14 APRIL 1961

INSTITUTE OF METALS: SPRING MEETING

METAL INDUSTRY

THE JOURNAL OF NON-FERROUS METALS

VOL 98 No 15

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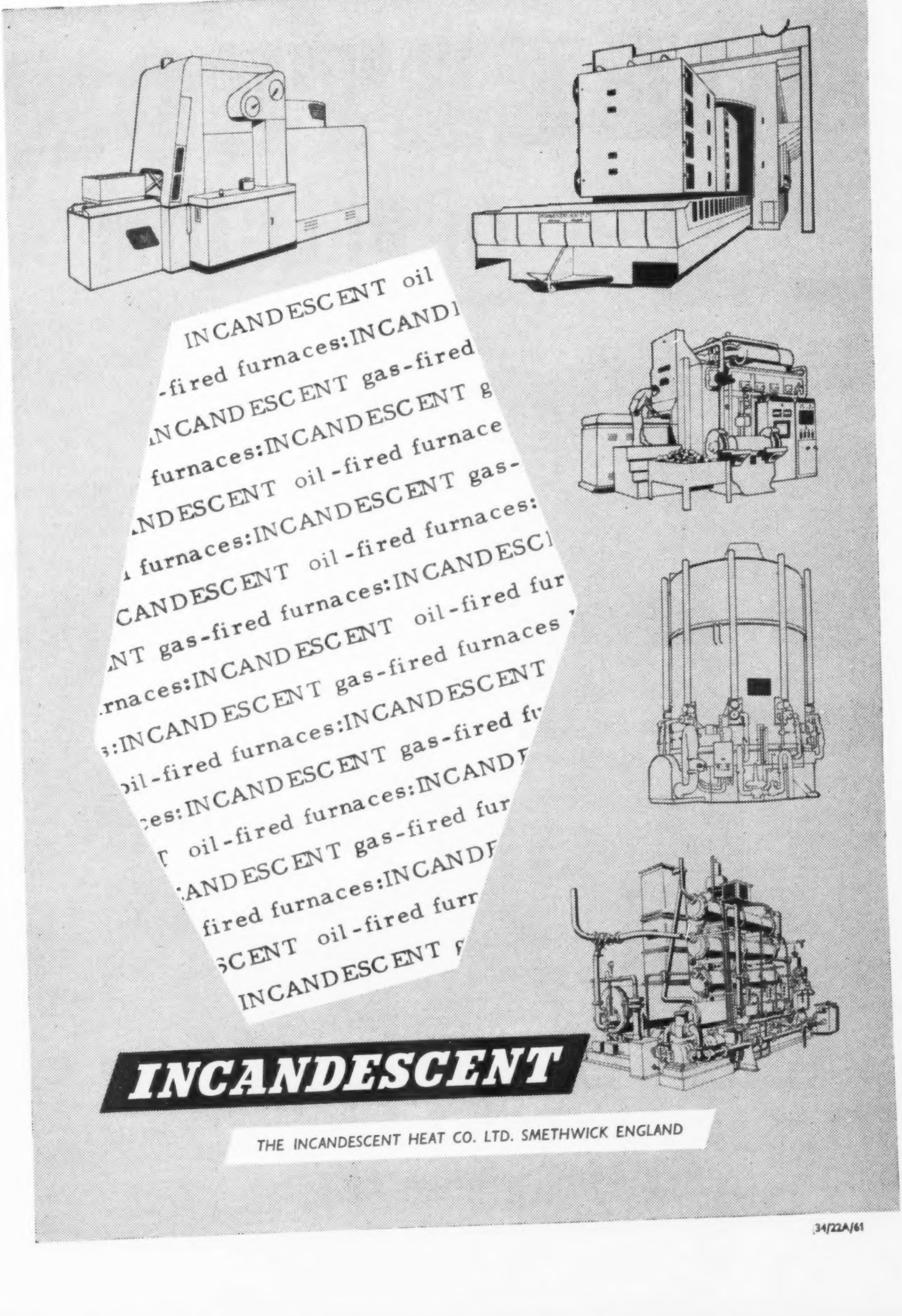
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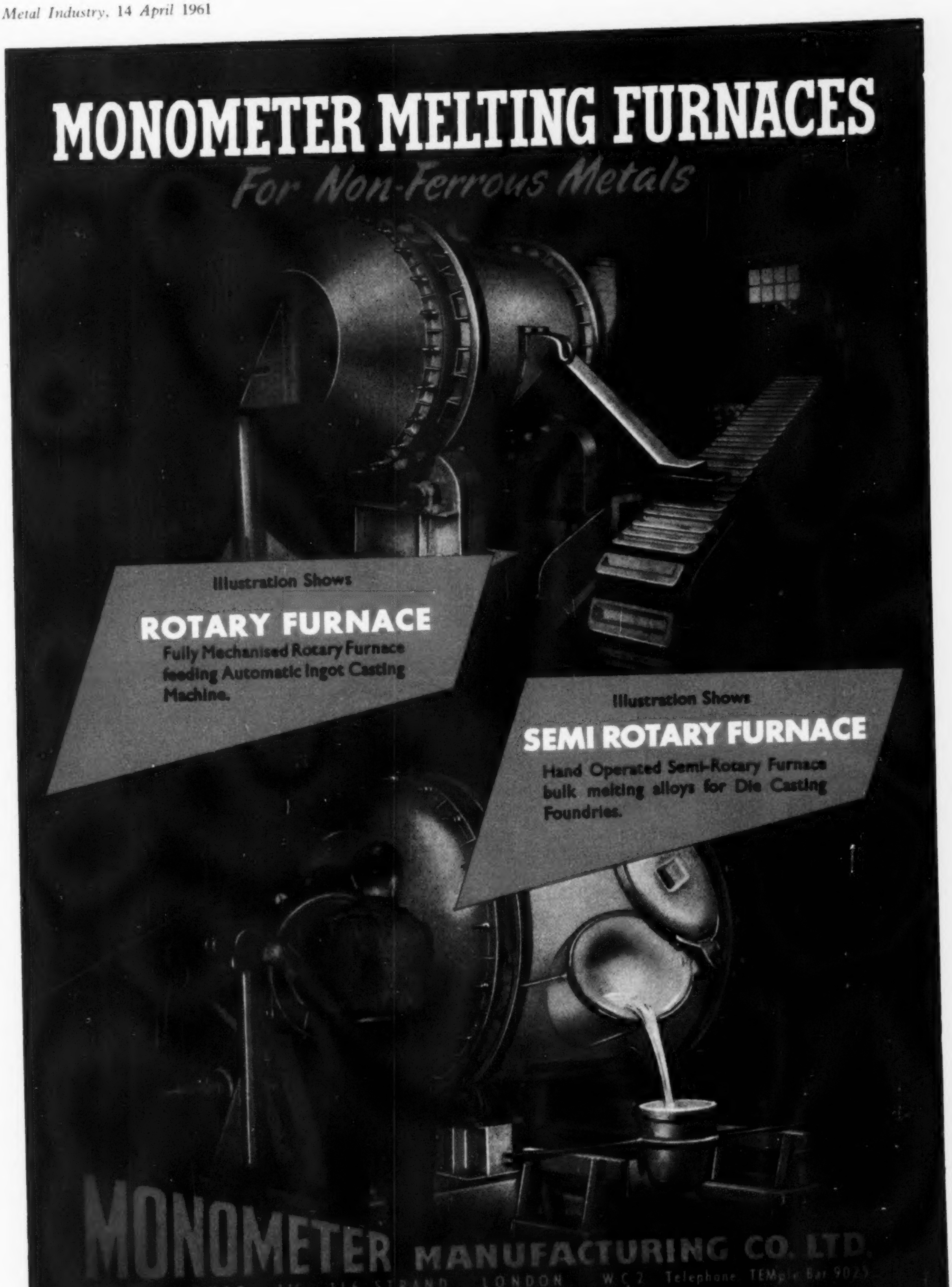
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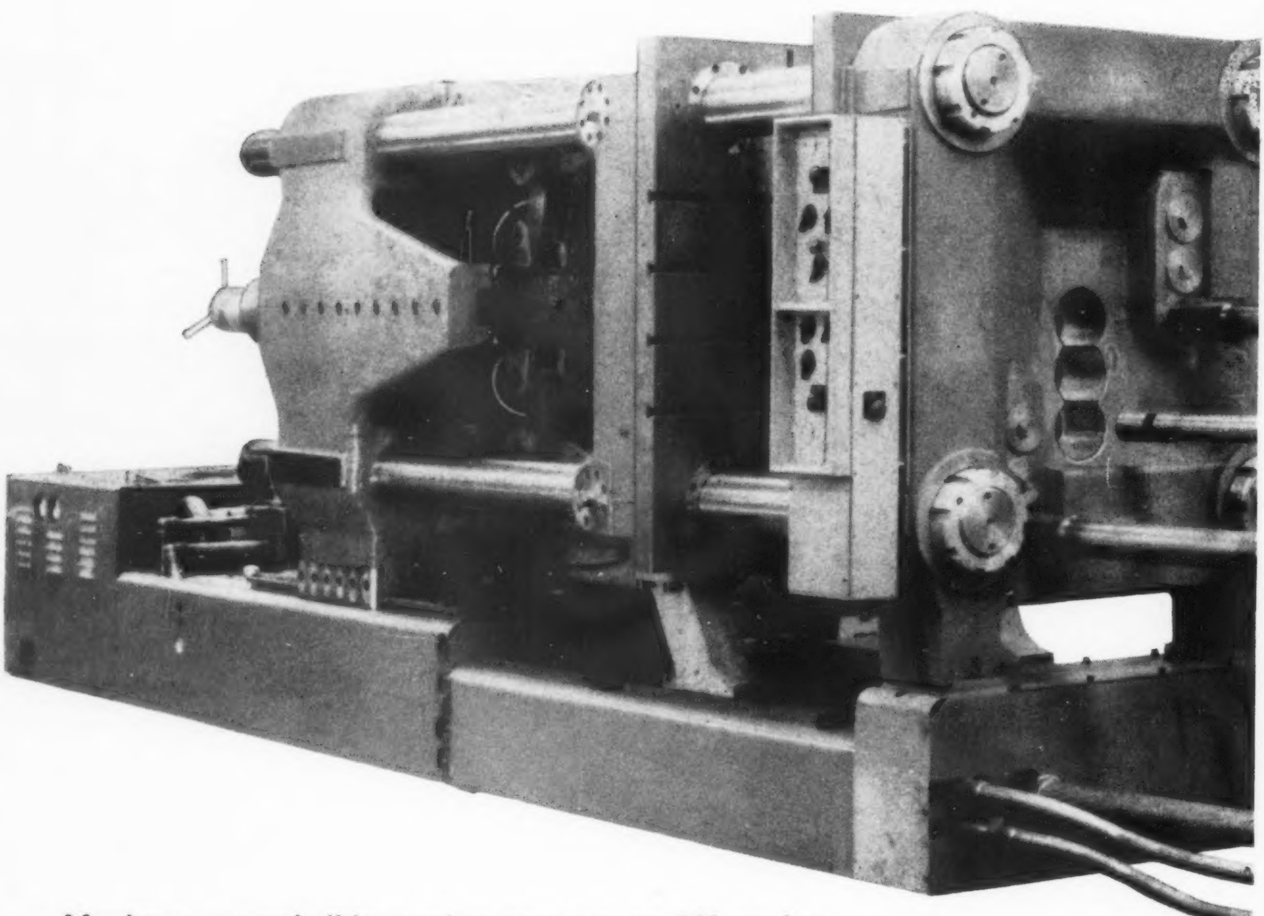

METAL INDUSTRY

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EDITOR: L. G. BERESFORD, B.Sc., F.I.M.

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METAL INDUSTRY

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Metallurgy for Engineers

THAT a knowledge of the properties of materials is essential to any engineer goes without saying. How he can best acquire such knowledge has been, and always will be, a matter for argument. The general principles to be followed in designing courses in metallurgy for engineers were recently discussed by Professor J. G. Ball in a Paper to the Institution of Mechanical Engineers. Not everyone will agree with his findings; to many metallurgists they savour too much of the physicist, and presuppose a knowledge of fundamentals possessed by few budding engineers. Nevertheless, Professor Ball's ideas at least form a fruitful basis for discussion.

In the first place, there seems little doubt that a subdivision of courses is required to suit various types of engineer. The ideal system would be to 'tailor" each course in metallurgy to suit not only a particular group of engineers (civil, chemical, mining, mechanical, etc.), but also the particular background of the class. This last is of particular importance in governing the treatment of those recent developments in metallurgy, which derive directly from physics and chemistry and which are understandable only in physical or chemical terms. In this connection Professor Ball contrasts the backgrounds of two extremes—the mining and the chemical engineer.

With those subdivisions of engineering where there is a more common basis for the development of the subject, i.e. mechanical, civil, aeronautical and electrical, the broad aim may be defined as imparting an understanding of the constitution and structure of materials. Given this, the engineer can select alloys for particular applications, discuss the causes of failure in service, and, most important, make designs appropriate to the properties of the alloys to be used. Owing to the time factor, any such course would have to be selective and should be so planned that the student is led to appreciate the significance of the information about metals in relation to his main subject of study. This, according to Professor Ball, is best achieved by dealing first with some of the more readily understood metallurgical properties and relating these to the fabrication history of a product to be used in engineering practice.

Such a syllabus would be divided into four main sections: the influence of manufacturing methods on properties; relationship between constitution and properties; methods of joining; effect of environment on metal behaviour. This syllabus is, of course, capable of wide variations in emphasis. For instance, when dealing with alloys in the second section, emphasis can be on phase equilibria if the background of the students is appropriate, or on practical issues where the students' knowledge of physics and chemistry is not sufficient. Another type of syllabus is that designed to acquaint the engineer with the behaviour of metals under stress. In such a course, constitutional features of the metal would be treated almost entirely from the standpoint of their influence on behaviour under stress, and a true metallurgical understanding of phase relationships would not be thought to be necessary.

In both the suggested syllabuses compromises are made between giving the engineer vocationally useful information and presenting the subject as a complete scientific discipline. A third method is to tackle the problem in the "pure science" way, in which the engineer is given the broadest conceptions of the behaviour of solids, so that although his knowledge of specific alloys or systems may be scanty, he can acquire information rapidly and put his knowledge to practical use.

Out of the MELTING POT

Still Learning SLOW progress continues to be made towards the understanding of the various factors concerned in the group of phenomena, collectively known as the Kramer effect, that involve the emission of low-energy electrons from solid surfaces, both metallic and non-metallic. Such progress supports the hope that, in due course, the understanding gained will be sufficient to permit the Kramer effect to be used as a basis of a sensitive method for investigating the surface condition of solids. For the present it is still much more a matter of investigating the effect of surface conditions (e.g. conditions resulting from mechanical treatments such as abrasion, filing, polishing, compression) and of numerous other factors on the electron emission (e.g. the delayed emission of electrons—"exo-electrons") rather than the measurement of emission as a means of obtaining evidence regarding the condition of a surface. This lack of certainty regarding the Kramer effect, that militates against its use as a research tool, is illustrated by the recent discovery that true delayed emission of exo-electrons from freshly abraded, filed or compressively strained metal surfaces does not occur in the absence of light. The intensity of light needed to induce photo-electron emission from mechanically treated metal surfaces is extremely low. Irradiation with X-rays does not induce delayed electron emission from mechanically worked metal surfaces, and, in fact, strongly de-activates them, so far as subsequent photo-emission is concerned, though, subsequently, recovery of photo-emission occurs. Investigations of the photo-electric wavelength thresholds and of the decay and recovery of photo-electric emission observed at various intervals after mechanical treatment as a function of wavelength are expected to contribute to an understanding of the increased photo-emission resulting from mechanical treatment of metal surfaces, and in particular of the question of whether this increase is caused solely by the lowering of the work function of the metal surface. The discovery that no electron emission occurs from abraded or deformed metal surfaces in darkness, will also necessitate the re-examination of the theory according to which the Russell effect (the blackening of photographic emulsions in contact with freshly worked metal surfaces) is due to the formation of hydrogen peroxide brought about by the emission of exo-electrons.

Proper Preparation IN theory, and for certain purposes also in practice, boron carbide, which is nowadays finding an increasing number of applications in hard metal compositions, cermets, materials in use in nuclear energy work, etc., can be made by heating a mixture of boron and carbon to a sufficiently high temperature. Attempts to use this procedure for preparing a range of boron-carbon compositions intended for the study of the phase composition and properties of such compositions proved, however, unsuccessful. Sintering of compacts of the mixture resulted in excessive volatilization of the boron and the formation of porous (40-75 per cent) products. Hot pressing in a graphite mould resulted in considerable oxidation and nitriding, and also considerable absorption of carbon. The oxidation and nitriding were avoided by working in argon. Lining of the graphite die with molybdenum or providing it with a coating of various refractory oxides in order to prevent carbon pick-up were not very successful. Finally, success was achieved by coating the inside of the graphite die with boron nitride. With this arrangement, dense specimens of boron-carbon compositions containing from 4·5 to 90 per cent carbon by weight could be produced by pressing for 7-15 minutes at 1,950° to 2,250°C. under pressures of 150-200 kg/cm². Microstructural and X-ray examination of compositions prepared in this way confirmed the existence of the previously known boron carbide $B_{12}C_3$ (B_4C) phase and also led to the discovery of another phase, richer in boron, and having a composition corresponding approximately to the formula $B_{12}C$. Some indication was also obtained of a wide range of solubility of boron in carbon. As usual these days, the thermoelectric properties and the electrical conductivity at different temperatures of the various compositions was measured. The B_4C compound is a semiconductor with a forbidden zone of 1·64 eV.

Cold Cold Extrusion HOT extrusion of aluminium and its alloys at temperatures above their recrystallization temperature naturally yields extruded products the mechanical properties of which are those of the metal in the annealed condition. In the case of aluminium and the non-heat-treatable alloys the mechanical properties of such sections can only be increased by cold drawing. The need for this additional operation can be avoided by using the cold extrusion process in which the billets to be extruded are at room temperature. One difficulty in the cold extrusion process arises from the heat generated during the extrusion process. This heat may result in the billet reaching temperatures which will cause some dropping off in strength along the length of the extruded section. To avoid this effect, cold extrusion has been carried out at high speeds, with the ram moving at up to 700 mm/sec. Such rapid extrusion leaves no time for the temperature of the billet to rise appreciably, but calls for specially designed and, unfortunately, expensive presses. It has now been suggested that an ordinary extrusion press and normal extrusion speeds can be used if the extrusion billets are first cooled to low temperatures (−60° to −70°C.) at which, however, there is as yet no increase in the resistance of the metal to deformation. Extrusion can then be carried out with the ram moving at, for example, 50-80 mm/sec. At this speed, and with an extrusion ratio of, for example, 30 per cent, the work hardening of the resulting extrusion is claimed to be higher than that of sections extruded at high speeds but without preliminary cooling of the billets. Dry ice can conveniently be used for cooling the billets. To avoid unsoundness of the extrusion, traces of the dry ice must be removed from the surface of the billets by a brief exposure of the latter to a stream of warm air immediately prior to extrusion. Alternatively, the billets can be cooled in a liquid bath (e.g. a silicone oil composition to which graphite may be added) the residue of which will then also act as a lubricant. It is also recommended to provide cooling (not refrigeration) for the extrusion press container and press tools.

Skimmer

Institute of Metals

Sir Ronald Prain addressing members of the Institute at the Annual General Meeting. In the centre is Prof. Hugh O'Neill with Mr. D. C. P. Neave on the left.

SPRING MEETING 1961

PRECEDED by an Extraordinary General Meeting called to discuss amendments to the Articles of Association, the Annual General Meeting of the **Institute of Metals** was held at the Hoare Memorial Hall, Church House, Great Smith Street, London, S.W.1, on Tuesday, March 21. The chair was taken by the President, **Sir Ronald Prain,** O.B.E., Hon. M.I.M.M., who welcomed members and visitors from overseas. The secretary, **Lieut.-Colonel S. C. Guillan,** T.D., then announced that since the 1960 Autumn Meeting 244 new members had been elected, and that the 1961 Autumn Meeting will be held in Brussels from Monday to Saturday, September 18-23.

The adoption of the Report of Council for the year ended December 31, 1960, was moved by the chairman, **Professor H. Ford,** D.Sc., Ph.D., M.I.Mech.E., Vice-President, seconding. The motion was approved.

The honorary treasurer (**Mr. D. P. C. Neave,** M.A., M.I.C.E., M.I.Mech.E.) presented his report and moved the adoption of the accounts. Being seconded by **Major C. J. P. Ball,** D.S.O., M.C., F.R.Ae.S., chairman of the Finance and General Purposes Committee, the motion was passed.

Election of Officers

The names of members elected to fill vacancies on the Council for the year 1961-62 were announced by the Secretary as follows:—President: **Prof. H. O'Neill,** M.Met., D.Sc., F.I.M. (head of the Department of Metallurgy, University College of Swansea, University of Wales). Vice-Presidents: **Mr. W. F. Randall,** B.Sc., A.R.S.M., M.I.E.E., F.I.M. (deputy chairman, Telegraph Construction and Maintenance Co. Ltd., and deputy chairman and managing director, Telcon Metals Ltd., Crawley)); **The Rt. Hon. The Earl of Verulam** (chairman, Enfield Rolling Mills Ltd., Brimsdown, Mddx.). Ordinary Members of Council: **Mr. N. I. Bond-Williams,** B.Sc., F.I.M. (director, Enfield Rolling Mills, Brimsdown, Mddx., and managing director, Aston Chain and Hook Co. Ltd., Birmingham); **Prof. A. H. Cottrell,** M.A., Ph.D., F.I.M., F.R.S. (Goldsmith's Professor of Metallurgy, University of Cambridge); **Mr. G. A. Rider** (deputy managing director, Birmid Industries Ltd., Birmingham).

As Senior Vice-President for 1961-62, the Council has elected The Rt. Hon. The Earl of Verulam, and he will be their nominee for the Presidency in 1962-63.

The chairman then called on **Dr. L. B. Pfeil,** O.B.E., F.I.M., F.R.S., Past-President, to move a vote of thanks to those members who, in accordance with the Articles of Association, now retire from the Council. These were:—Past - President: **Major C. J. P. Ball,** D.S.O., M.C., F.R.Ae.S.; Vice-President: **Mr. R. D. Hamer,** B.Sc., F.R.I.C., F.I.M.; Ordinary Members of Council: **Prof. J. W. Cuthbertson,** D.Sc., A.M.I.E.E., F.I.M., and **Mr. F. Waine, J.P.**

Sir Ronald Prain introduced the new President of the Institute, Prof. H. O'Neill, M.Met., D.Sc., F.I.M.; and, having invested him with the Presidential Badge, inducted him into the chair.

Having thanked the members for electing him as their President, Prof. O'Neill called on **Mr. G. L. Bailey,** C.B.E., M.Sc., F.I.M., Past-President, to propose a vote of thanks to Sir Ronald Prain for his services to the Institute as President in the past year.

Prof. H. O'Neill
President

The Earl of Verulam
Senior Vice-President

W. F. Randall
Vice-President

N. I. Bond-Williams
Member of Council

Prof. A. H Cottrell
Member of Council

G. A. Rider
Member of Council

Prof. A. J. Murphy, M.Sc., F.I.M., Past-President, seconded the motion, which, on being put to the meeting, was carried.

The new President then delivered his address on the subject:—"Some Thoughts on Metallurgical Education in an Industrial Society".

Presidential Address

In the course of his remarks, Prof. O'Neill said:—"The First World War showed that we were deficient in technologists and in the application of science to industry. Even by 1930 the output of metallurgical graduates was still very small, and in those hard times it was very difficult for a graduate to find a suitable job in Britain. The profession was lacking in prestige, and most industrialists had still to be converted to the idea of employing appreciable numbers of university men. It is curious that formal metallurgical training was slow to be recognized here, for it had long played a part in Central Europe.

"Evidence to this effect may be gathered from the *Journal* of Lady Charlotte Guest. At a period when women were supposed to be unemancipated, this remarkable lady was for a time the secretary of the Dowlais Iron Co., which soon had the largest works in the world. In 1842 she visited the metal-producing districts of Germany and Bohemia, and in her *Journal* wrote that at Lanterberg and Ostrode 'there is a large establishment of mining officers, all of whom are instructed in chemistry and other sciences relating to their art: they are dressed in uniform, blue and red, and are of different grades. . . . There are schools at Clausthal for the instruction of the young men, a museum, and a large collection of models. Professors of Chemistry who are attached to the establishment reside there, and are constantly employed in making experiments and scientific researches'.

"It is interesting that these German schools went in for museums and made extensive use of models. During our Scandinavian tour last year, members of the Institute had an opportunity of seeing industrial museums in those countries. In Britain we seem to be rather short of such exhibits, but the recent developments in the Science Museum at South Kensington now enable visitors to learn much more about the metallurgy of iron and steel. The Birmingham City Museum of Science and Industry is also making good progress, and I am glad to report that we now have the Industrial Museum of South Wales in Swansea.

"The early German metallurgical schools were known to the copper-smelting Vivians of Swansea, for John Henry Vivian studied there at the beginning of the nineteenth century, and so did later members of the family. By comparison, it is worth recalling that only in 1851 was our first 'Government School of Mines and of Science Applied to the Arts' started at South Kensington.

"Considering the present requirements of industry and the research laboratories, the recruitment of metallurgical students to our expanding universities is a matter of some concern. It appears that about 6 per cent of students entering for technology are metallurgists and they form about 1 per cent of the total admissions.

"In addition to the universities, we now have the Colleges of Advanced Technology, which award the Diploma in Technology. Their report for the year April 1959-March 1960 shows that 129 Dip. Techs. were conferred, of which 8 per cent were to metallurgists. But of all the students taking courses in the colleges during that year only 3 per cent were studying metallurgy. Furthermore, if we take the difference between the number of students in the first and third years of study as a measure of increasing recruitment (neglecting those who have meanwhile left the colleges for one reason or another), then metallurgy shows a 23 per cent increase, but chemical engineering has grown by 244 per cent and mechanical with production engineering by 105 per cent. Recruitment to our subject appears to be relatively stagnant, and it looks as though metallurgy still suffers from a lack of prestige.

"There has recently been a good deal of discussion about the relative importance of teaching and of research in our universities. I would support the view of John Henry Newman that teaching and the promotion of interplay between the various disciplines is the primary function of a university. It is generally agreed that a lecturer who is doing research proves to be the more stimulating teacher.

"The personal aspect of teaching may soon be called into question. It

The President, Prof. Hugh O'Neill presenting the Institute of Metals (Platinum) Medal to Major C. J. P. Ball

is being asked: Can technology benefit teaching itself? Can automation be applied to the lecture room? In the United States, automatic teaching devices for schools are already on the market.

"There has also been some recent criticism of university research. 'Are we satisfied with the universities', asks Dr. N. P. Allen, 'with their output of Ph.D.'s duly stamped after having swelled for three years the research departments of the more energetic professors?' Sir Andrew McCance is reported as saying: 'I have come to believe that extra time spent in research work after a degree has been taken is in many cases a waste of time . . . postgraduate students are not asked to think for themselves'.

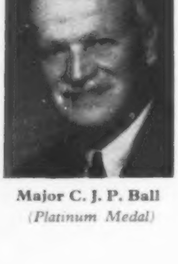
"Why is it supposed to be better to start training as a researcher outside the university? In the matter of university research there are also conflicting views about 'string and sealing wax methods' versus the use of expensive apparatus. With the provision of better financial grants to universities I think that we should now proceed with the latter. Another question is the fruitfulness of the single experimenter as against the research team. Does the member of a team do more thinking for himself than the individual researcher?"

A vote of thanks to the President for his address was proposed by **Prof. J. G. Ball** and carried with acclamation.

Awards of Medals

The President presented the Institute of Metals (Platinum) Medal to **Major C. J. P. Ball,** D.S.O., M.C., F.R.Ae.S., in recognition of his outstanding services to the non-ferrous metal industries and, in particular, the magnesium industry.

Major Ball pioneered in Britain the first real usage of the important light magnesium alloys developed by the Germans. He took the initiative in the formation of Magnesium Elektron Ltd., and was responsible for the erection of the factory at Clifton Junction. With the outbreak of war in 1939, the demand for magnesium went up by



Major C. J. P. Ball
(Platinum Medal)

Dr. P. B. Hirsch
(Rosenhain Medal)

leaps and bounds, and the plant was doubled in 1940. Later, it became clear that still greater production would be needed, and in 1942 Magnesium Elektron Ltd., on behalf of His Majesty's Government, erected a factory near Burnley of rather larger capacity.

After the entry into the war of the United States in December 1941, the demand for magnesium increased so enormously that there was little possibility of its ever being met by available production. Following representations to the British Government in 1941, Major Ball, with two of his staff, flew to the United States to advise the U.S. Government on the problem of how to increase production rapidly. The U.S. Government asked Magnesium Elektron Ltd. to provide plans to train personnel to erect and operate the largest magnesium plant in the world, near Boulder Dam. Under the direction of Major Ball and his technical staff, work was driven ahead at a remarkable pace. Within ten months from breaking ground the first metal was produced, the plant when in full production giving 10 per cent more than planned figures.

Since the early days, Major Ball had realized the benefits which would result if successful magnesium-zirconium alloys could be evolved, and had insisted that development work should be carried on even during the war years. After the war, in spite of the uncertain outlook for magnesium, he continued to support this research, and success came at a time when aircraft designers were in desperate need of strong light alloys capable of operating at elevated temperatures. The development of these zirconium alloys allowed full advantage to be taken of the effects of rare-earth metals in promoting resistance to creep at high temperatures.

The Rosenhain Medal was awarded and presented later in the week to **Dr. P. B. Hirsch,** in recognition of his outstanding contributions in the fields of physical metallurgy and metal physics.

Dr. Hirsch started his research career in the Cavendish Laboratory in 1946, when, in collaboration with the late Mr. J. N. Kellar, he developed an X-ray micro-beam technique to study the fine structure of cold-worked metals. These studies led to valuable information on the distribution of dislocations in the cold-worked state, and also threw light on the phenomena of recovery and recrystallization.

In 1954, Dr. Hirsch initiated electron microscope work on the examination of metal foils, so thin that they were transparent to the electron beam, which directly revealed the existence of dislocations, both in annealed and in deformed metals. Not only were observations made of individual dislocations in the foils, but also studies were made of their movements and their interactions with each other.

The scope of the work was extended to include metals deformed in various ways, e.g. at elevated temperatures and by fatigue, and also the defects introduced by quenching from high temperatures. At the same time, Dr. Hirsch was not content to accept the pictures of dislocations at their face value, but initiated work designed to interpret the various diffraction effects which were apparent in the electron micrographs.

In recent years, Dr. Hirsch has also taken a considerable interest in the basic mechanical properties of metals, and by analysis of results on the temperature-dependence of stress/strain curves of single-crystal and polycrystalline pure metals, he has made a substantial contribution to the theory of work-hardening.

The Secretary announced the award of the W. H. A. Robertson Medal and Premium to **Y. Yokote** and **S. Nomura** for their Paper on "Rolling Aluminium Foil: An Experimental Study of a Modern Mill" (*J. Inst. Met.*, 1960, **88,** 241).

Special arrangements will be made for the presentation of the medal to the authors, who reside in Japan.

This concluded the business of the annual general meeting and the President brought the session to its close.

On the evening of Tuesday, March 21, the Fifty-First May Lecture was presented, the lecturer being **Prof. M. Polanyi,** D.Sc., F.R.S., whose subject was "Science: Academic and Industrial". The President called on **Mr. H. W. G. Hignett,** B.Sc., F.R.I.C., F.I.M., Vice-President, to propose a vote of thanks to the lecturer, and the motion was acclaimed.

A Conversazione and Exhibition were staged for the entertainment of members and guests during the evening of Wednesday, March 22, and on Thursday evening the Annual Dinner and Dance was held at Grosvenor House, Park Lane.

At the latter function, after the Loyal Toast had been honoured, **Mr. W. F. Cartwright,** M.I.Mech.E., D.L., J.P., President of the Iron and Steel Institute, proposed a toast to "The Institute of Metals and the Non-Ferrous Metal Industries". He referred to the long association between the two institutes and the arrangements recently concluded which would bring them into even closer co-operation with the Institution of Metallurgists. The President, **Prof. Hugh O'Neill,** in reply, thanked Mr. Cartwright for his good wishes.

The toast of "The Guests" was proposed by the Senior Vice-President, **The Earl of Verulam,** and **Sir Harold Roxbee-Cox,** D.Sc., Ph.D., F.R.Ae.S., replied.

Prof. R. W. K. Honeycombe, Dr. E. G. West, Mr. L. Rotherham and Prof. J. G. Ball

Mr. G. L. Bailey, Mr. D. S. Burwood, Dr. J. W. Jenkin, Mr. A. R. Powell and Dr. L. B. Pfeil

Technical Sessions

Discussion on Extrusion

AMONG the sessions at the Institute of Metals Spring Meeting, that on Thursday, March 23, was devoted to a discussion on "Extrusion", arranged by the Metallurgical Engineering Committee. **Prof. H. Ford,** D.Sc., Ph.D., Wh.Sch., M.I.Mech.E., Vice-President and chairman of the Metallurgical Engineering Committee, was in the chair, and the following Papers were presented and discussed: "The Cold Extrusion of Metals, Using Lubrication at Slow Speeds", by Mr. R. J. Wilcox and Prof. P. W. Whitton (*Journal*, Serial No. 1911; May, 1959). "Further Experiments on the Cold Extrusion of Metals, Using Lubrication at Slow Speeds", by Mr. R. J. Wilcox and Prof. P. W. Whitton (*Journal*, Serial No. 1957; Dec., 1959). "Resistance to Deformation of Aluminium and Some Aluminium Alloys: Its Dependence on Temperature and Rate of Deformation", by Mr. R. R. Arnold and Mr. R. J. Parker (*Journal*, Serial No. 1978; Feb., 1960). "Temperature Changes Occurring During the Extrusion of Aluminium, Tin and Lead", by Prof. A. R. E. Singer and Dr. J. W. Coakham (*Journal*, Serial No. 2048; Feb., 1961). "Temperature Changes Associated with Speed Variations During Extrusion", by Prof. A. R. E. Singer and Mr. S. J. K. Al-Samarrai (*Journal*, Serial No. 2056; Mar., 1961).

The five Papers were introduced by **Dr. J. M. Alexander,** of the City and Guilds of London Institute.

Abstracts of the Papers and a condensed version of the discussion are given on this and ensuing pages.

R. J. Wilcox

Prof. P. W. Whitton

The Cold Extrusion of Metals Using Lubrication at Slow Speeds

By R. J. WILCOX, B.Sc.Tech., A.Inst.P., and P. W. WHITTON, B.Sc.(Eng.), Ph.D., A.M.I.Mech.E.

IN an investigation into extrusion ratio, die angle and the effect of container wall friction, super-pure aluminium was extruded by the direct and inverted methods using dies of semi-cone angle varying from 30° to 90° and of extrusion ratio varying from 2:1 to 150:1. Only one material was used, one speed (0·44 in/min.) and one lubricant (lanoline).

A general equation relating the inverted-extrusion pressure to the semi-die angle and extrusion ratio has been derived empirically by using a mean value of yield stress for each extrusion ratio; this mean value is taken to be that at the logarithmic strain appertaining to the extrusion ratio considered. The general equation so derived is a summary of the individual equations obtained for each particular angle of die and covers a much wider range of conditions than any hitherto presented. Comparison of results for 90° dies with published data obtained under nearly identical conditions shows that extrusion pressures predicted by the equation are accurate to within ±6 per cent of the experimentally determined pressures for various materials. It is envisaged that the equation will have general application for hot and cold extrusion provided that the appropriate mean yield stress is known accurately.

The pressure for direct extrusion can easily be obtained if the coefficient of friction between billet and container wall is known.

Dead-metal formation and pressure due to redundant work were examined, and the optimum die angle for minimum extrusion pressure is shown to be dependent on the extrusion ratio.

Further Experiments on the Cold Extrusion of Metals Using Lubrication at Slow Speeds

By R. J. WILCOX, B.Sc.Tech., A.Inst.P., and P. W. WHITTON, B.Sc.(Eng.), Ph.D., A.M.I.Mech.E.

COPPER and two aluminium alloys possessing different strain-hardening characteristics were cold extruded with lubrication at a slow speed (0·44 in/min.), over as wide a range of die angles and extrusion ratios as was practicable. Inverted-extrusion pressures for these materials calculated from an empirical equation derived from earlier experiments, agree with experimental values within ±7 per cent. This equation has now been shown to be applicable over a wide range of conditions to a number of very different materials extruded cold at slow speeds. Two surface defects that occur when true lubricated flow breaks down were examined, the "fir-tree" defect and the "mottled-surface" defect.

The onset of the former appears to be related to frictional conditions on the die face, and since conical dies are of larger die-surface area, for the same extrusion ratio, than flat-faced dies, it is reasonable to expect this defect to occur more easily. Since the defect ceased with 90° dies when the extrusion ratio was increased, a further factor which must be of some importance is the actual stress acting on the deforming metal.

The "mottled-surface" defect is most likely due to a process of stick/slip, localized zones on the die face causing momentary internal shearing. This internal shearing would then lead to a decrease in extrusion pressure and the resulting mottled surface is a reflection of the stick/slip that occurs on the die face, but elongated in the direction of extrusion.

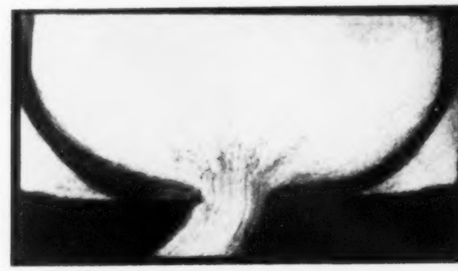
DISCUSSION

R. Chadwick (Imperial Chemical Industries Ltd., Metals Division, Birmingham): Dr. Alexander, in his introduction of the Papers, mentioned two important factors which had to be considered, i.e. the prediction by mathematical and physical methods of the pressures involved in extrusion, and also the prediction of the mechanisms involved, but I would like to put those in the opposite order.

May I make the point first of all that, in my view, cold and hot extrusion are one and the same process? The same mechanisms are involved. I know that more often cold extrusion tends to be lubricated and more often hot extrusion tends to be non-lubricated, but nevertheless both mechanisms are used, both hot and cold.

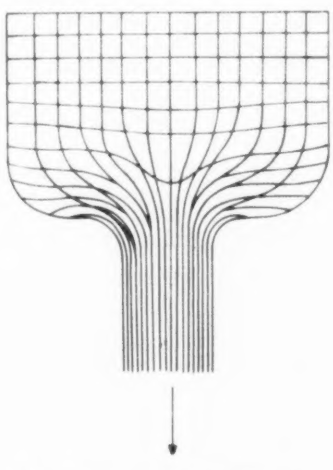
Fig. 1 shows the butt-end of a billet, using the convention of downwards extrusion, which is simpler. Flow takes place along the lines shown, and it will be noted that there is a dead-metal zone. In non-lubricated extrusion, direct extrusion, there is always this dead-metal zone in which no movement takes place throughout the extrusion from beginning to end. Maximum flow takes place along the lines shown, and also it tends to be at a maximum

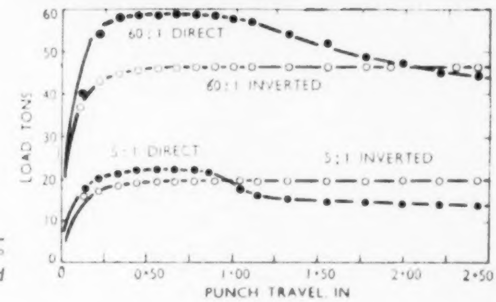
Fig. 1—Copper alloy billet partly extruded



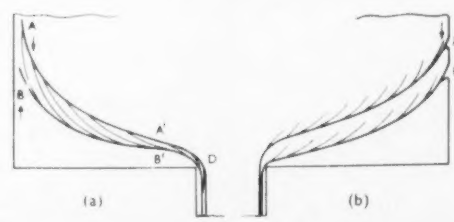
Right: Fig. 2—Flow in high strength aluminium alloy billet

Fig. 3—Fully lubricated extrusion

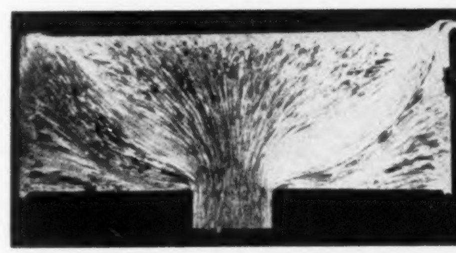




Right: Fig. 4—Autographic diagrams: 90° die (Wilcox and Whitton)



Right: Fig. 5—Extrusion mechanisms



Right: Fig. 6—Extrusion defect in aluminium alloy

towards the outside of the product.

Fig. 2 depicts a high-strength aluminium alloy extrusion which shows the extent to which the high rate of shear inside the metal is down the sides, and then comes round to the orifice, into the surface part of the product. The dead-metal zone is again shown in the corner. The characteristic of direct extrusion is that the billet metal has been pushed through the container, and a great deal of work is involved in this complex flow in the container as well as the deformation involved in pushing the metal through the die.

Fig. 3 shows what one gets in fully lubricated extrusion, where the deformation through the container is uniform or, rather, where there is no deformation when the metal moves through the container, and it is only deformed just as it approaches the die.

I would like to compare that with indirect extrusion, because in indirect extrusion the billet is stationary in the container. There is no movement between the billet and the container, but the die is pushed into the billet in the direction indicated in the diagram, so that the flow takes place only in the neighbourhood of the die, and the flow mechanism is the same throughout the extrusion.

The point I want to make there is that really indirect extrusion is the same, basically, as fully lubricated direct extrusion, because there are no forces involved and there is no internal stirring up of the material involved. In fully lubricated direct extrusion or indirect extrusion, the outside of the billet should form the outside of the product, and it is important to have the die arranged in such a way that this can take place round the die.

Turning to the Paper by Wilcox and Whitton, Fig. 4, is the authors' Fig. 2. The curves for inverted extrusion show that there is a constant load once the extrusion is started, because there is a constant mechanism of deformation throughout the process. In indirect extrusion there is a higher load, but at a point which is not more than about two-fifths of the way through the extrusion of the billet the pressure suddenly starts to fall. That seems a very extraordinary thing to happen, because it is difficult to see why, at that point, one should get this sudden drop. The authors, in talking about this, say that at that point they got the formation of a dead-metal zone, and then they go on to say that they got a coring point, i.e. where the back end of the billet turns round and leaves a hollow part in the inside. I want to deal with this dead-metal zone, because it will be seen that in Fig. 1 the dead-metal zone was the original cast structure, and when you get a dead-metal zone, normally it is dead from the start; it does not suddenly become dead half-way through. I discussed this with Wilcox, and it is as I suspected: what is happening here is not what we normally mean by a dead-metal zone. You get a mechanism taking place because the lubricant is being drawn into the product, and Fig. 5 will illustrate what I mean.

On the left there is unlubricated direct extrusion, and there are shown the zones of maximum shear coming down and going through the die. On the right are shown the conditions for partial lubrication, and here there are differences in wall friction on different parts of the wall; particularly, flow is prevented at one point by the corner, and there is triaxial stress at some point (E), which causes the skin to break, and suddenly a crack spreads right through to the point shown, and this greatly reduces the pressure. The extrusion then takes place over this lubricant film, and the lubricant film is finally drawn into the

R. R. Arnold

R. J. Parker

Prof. A. R. E. Singer

J. W. Coakham

S. H. K. Al-Samarrai

product underneath the surface. In a partial lubrication system such as with oxide scale on copper, this can take place two or three times, and a series of films can be obtained.

An example of such a film in an aluminium alloy is given in Fig. 6, and it can be seen that there has been a breakdown at one point, and there is a film coming through. There is a more conspicuous one at another point and coming down and into the billet. The fact that this is at the corner and is three-quarters extruded is sheer accident. This really started part of the way down the billet wall.

Wilcox and Whitton obtained these so-called dead-metal zones in a very large proportion of their work both in indirect and direct extrusion, and roughly half of their products contained these drawn-in lubricant films. The sort of conditions that gave rise to a product of this kind are of little interest commercially and, therefore, the analysis of the stresses arising in a system in which one has got a sort of artificial die formed by part of the billet and the whole thing is sliding through this nicely contoured dead-metal zone, is something which provides an interesting academic exercise, but all these stress data are really of very little value.

In this connection it is important to know that partial lubrication (and here you have the ends but not the side faces lubricated) is what is always regarded as the dangerous condition in industrial extrusion. There must either be no lubrication, in which case there is no movement between the billet material and the container walls, or there must be such lubrication that one can get the whole thing moving down, as in glass extrusion, and moving over the die face and down into the product. With inverted extrusion, the dies must be designed so that in between the original billet and the product there is flow of the surface of the billet over the die face.

It is perhaps significant to point out that in the second Paper by Wilcox and Whitton we are again dealing with stresses and mechanisms in which defective products are formed, and in so far as this Paper tells us the conditions under which they are formed it is valuable, but in so far as it analyses the stresses during the formation, its value is not so great.

F. A. Hodierne (Tube Investments Ltd., Birmingham): My own current interests are in the experimental extrusion of steel at low extrusion ratios and this interest in low extrusion ratios has led me, to different methods of calculation to those used by Wilcox and Whitton.

From the remarks in the Paper about dead-metal zones with angle dies it appears that the entry diameter of the die is less than the container diameter. If so, these dimensions should be clearly stated in

Resistance to Deformation of Aluminium and Some Aluminium Alloys

By R. R. ARNOLD, B. Eng., and R. J. PARKER, A.M.I.Mech.E.

RESISTANCE to compressive deformation of commercially pure aluminium, three non-heat-treatable aluminium alloys (aluminium-manganese, aluminium-2¼ per cent magnesium, and aluminium-5 per cent magnesium) and two heat-treatable aluminium alloys (aluminium-silicon-magnesium and aluminium-copper-silicon-magnesium) has been determined by experiments on a cam plastometer. Data are presented for strain rates within the range 1 to 30 in/in/sec., and temperatures varying from 300° to 550° C. The resistance to deformation of aluminium alloys in the hot-working range varies greatly; for example, the value for the high-strength aluminium-5 per cent magnesium alloy at 300° C. is about eight times that of commercially pure aluminium at 500° C. The higher-strength alloys were susceptible to thermal-softening effects, and resistance to deformation of these materials decreased after moderate reductions.

Temperature Changes Occurring During the Extrusion of Aluminium, Tin and Lead

By PROFESSOR A. R. E. SINGER, B.Sc., Ph.D., and J. W. COAKHAM, Ph.D.

THE temperature at which extrusions emerge from the die has been measured in the case of commercially-pure aluminium, super-pure aluminium, tin, and lead, extruded on a 100-ton laboratory press. In the main series of experiments, the speed of extrusion was varied over the range 1-30 in/min. and the temperature rise was shown to be markedly dependent upon speed. The emergent temperature rose above that of the billet, and in some cases the rise was as great as 200° C. It always occurred in three stages. A rapid initial rise was followed by a slow secondary rise persisting during the greater part of the ram travel. Ultimately, there was a sharp rise in temperature as the last 10 per cent of the billet was extruded. The pattern of the temperature rise is shown to be dependent on the physical properties of the materials and the extrusion ratio and speed. The temperature rise is also shown to be proportional to the logarithm of the speed of extrusion for the range and conditions investigated.

Temperature Changes Associated with Speed Variation during Extrusion

By PROFESSOR A. R. E. SINGER, B.Sc., Ph.D., and S. H. K. Al-SAMARRAI, B.Sc.

THE emergent temperature of an extrusion is an important factor in many industrial processes, and a thorough understanding of the relationship between temperature rise and speed might well lead to better speed regulation and a possible decrease in overall extrusion time, without substantial damage to the extruded material.

The effects of extrusion ratio, extrusion speed, and speed changes on the emergent temperature of lead and high-purity aluminium have been investigated. An attempt is also made to correlate the observations with theoretical calculations based on considerations of heat flow during the process.

The equipment for the experimental work consisted of an extrusion container, mounted on a 100-ton hydraulic press, that was directly driven by a high-speed axial plunger pump, and was capable of having its ram speed accurately controlled at any value between zero and 30 in/min. Billets of lead and high-purity aluminium of 2 and 1½ in. dia. respectively, were extruded cold by the direct process through flat-faced dies to form round rod. The temperature of the extrusion as it emerged from the die was measured by means of an open-ended, two-pronged Chromel/Alumel thermocouple and a high-speed mirror galvanometer. Ram travel, pressure, time, and temperature were all recorded simultaneously with a 16-mm. ciné camera.

Aluminium and lead were extruded at several extrusion ratios, using constant ram speeds, stepped variations, and speed programmes within the range 30-1 in/min.

The President and his daughter

order that the scope of application of the results can be correctly assessed.

Prof. W. Johnson (Manchester College of Science and Technology): It was in 1947 that Hill gave his first solutions to extrusion, and he described purely the steady state problem. Consider what happens at the end of this process. It is a very much more complicated problem, and it has not yet been solved. The situations which arise have not been solved exactly using slip line field methods, but what has been done is to use, and I think use successfully, the method of limit analysis. By using elementary algebra, one can establish a very simple mechanism showing how the extrusion process alters. First of all, as the ram rod advances, if one has a relatively long billet extruding, using a simple form of extrusion, one has a steady state established, so that as the punch advances there is no alteration in the shape of the deformation zone. But things do start to alter immediately that punch gets somewhere near the edge of the deformation zone. One then moves into an unsteady state, and at some subsequent period the materials will start to lift off the bottom, and what is known as coring follows. If one establishes some upper balance, one can get a sequence of different mechanisms and can show, by using a fairly elementary criterion, how one will fade into the other. It is not exact, of course, but it provides a rational way of understanding, to my mind, how complex the extrusion process is.

Mr. Ursell (Imperial Chemical Industries Ltd.): Referring to Prof. Singer's Paper, I would have thought that with the lubricated extrusion used for super-pure aluminium, the tendency would have been for the temperatures to remain more constant in that the majority of the work is done immediately above the die face, whereas with the other extrusions which are essentially unlubricated—I believe that it is specifically stated that a certain amount of material was left in the container—there is a tremendous amount of working throughout the whole of the billet building up the temperature even at the back and in contact with the pressure pad, and, therefore, producing a much more rapid rise in temperature.

It will be interesting in that context, if Prof. Singer has done any experiments with the other metals which were unlubricated in the lubricated stage, to say how the temperature increases compare.

I believe that Prof. Singer states that frictional heating is only about 20 per cent of the total and, therefore, would not materially affect the results. I suggest that the majority of the frictional heating, particularly with lubricated extrusion, is on the surface and, therefore, that 20 per cent would materially affect the surface of the extrusion, which is, in fact, the part that is being measured.

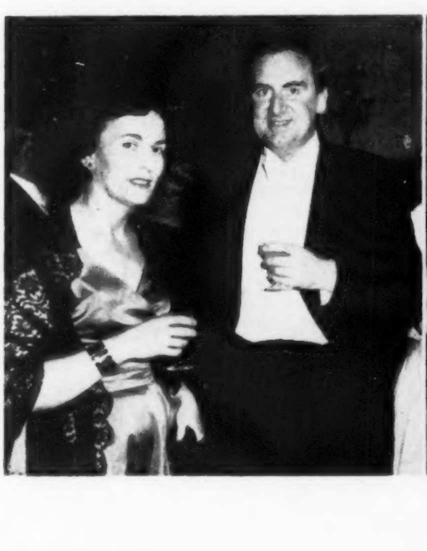
Dr. E. A. Bloch (Switzerland): The pressure speed in normal extrusion of aluminium alloys is rather low compared with the speed usually applied for metals with a higher melting point. This is mainly due to the fact that the range between the temperature at which these materials may be plastically deformed with little force and the temperature of hot shortness is rather narrow. In most of the cases it is necessary to dissipate a great amount of the heat arising during deformation into the pressing tools (die, container, pressure disc). Heat conduction, however, is a time-taking process. Pressing too quickly leads to overheating followed by the well-known fir-tree cracking of the extrusion.

As it ensues from the flow of material, and as it has also clearly been stated by Singer and Coakham, the heat originates in a conical zone in front of the die inlet. The resulting heat flows partly into the die and partly backwards into the billet. Owing to the far better heat conductivity of aluminium in comparison with steel, the latter portion is by far more important. Under highly simplified assumptions, the temperature distribution in the billet can be figured out. If the extrusion press is suddenly stopped, the heat generated in the deformation zone flows back into the non-extruded part of the billet. After a second, the back part of the billet up to the distance l (called heat conduction path in the following) from the deformation zone still shows the initial temperature; over the distance l the temperature of the material goes up to the temperature of the emergent extrusion. Now if the extrusion press is in operation, the material which is heating up is transported forward to the die, and through the die to the outlet.

The heat conduction from the deformation zone backward to the billet can be compared to a person who tries to descend an escalator going up. If the escalator moves faster upward than the person is able to descend, the latter will never get down. If the upward movement of the escalator is slower, however, the person slowly, though surely, will get down. By a similar consideration we gained a simple theory for the heat flow in extruding, the forecast of which conformed satisfactorily with the results of tests carried out in one of our works.

Similar to the calculations of Singer and Al-Samarrai, we found that at low ram speeds the heat flows farther back into the billet than at higher speeds. At a certain critical extrusion speed, the heat conduction path equals the billet path per unit of time. This critical speed corresponds about to the transition between the steep rise and the flat upper range in Fig. 10 of the Paper of Singer and Al-Samarrai, where the theoretical increase of temperature versus ram speed is plotted. Above this critical speed, the material entering the deformation zone shows always the same temperature if the wall friction is disregarded. Considering that the deformation, and thereby the heating, is always the same, the outlet temperature of the extrusion remains constant after stationary flow conditions have set in at the front end. However, if the extrusion speed is below the critical speed, some heat flows back into the still unextruded part of the billet. Whether

Prof. and Mrs. A. H. Cottrell



Mr. and Mrs. R. Smith, Mr. and Mrs. S. A. Hiscock, Mr. J. Oldroyd, Miss E. Oldroyd

Dr. and Mrs. G. L. Miller, Mr. and Mrs. P. S. Bryant

Dr. W. Betteridge, Mr. D. W. Rhys, Mr. F. S. Clements, Mr. J. R. Knight

an accumulation of heat combined with a current increase of the temperature of the emergent extrusion will then take place greatly depends on the amount of heat which can be dissipated into the container and the pressure disc. It can easily be conceived, and the test results of Singer and Al-Samarrai seem to confirm this, that by a suitable variation of the extrusion speed and thus of the heat dissipation, a constant emergent temperature may be reached, thus avoiding an overheating of the back end.

Extruding with a constant temperature is probably the most important improvement still to be gained in conventional hot-extruding of aluminium alloys.

It is rather interesting to consider the consequences which will be brought about by isothermal extruding in the upper speed range. The conclusion has already been drawn that such a high-speed isothermal extrusion must be possible. The extrusion speed can either be constant or variable as long as it lies above the critical value. It is easy to understand that under these conditions the heating up of the material in extrusion is very considerable, since approximately three-quarters at least of the heat of deformation remains in the emerging extrusion. To avoid the temperature range of hot shortness, it is necessary to start with a lower than the normal billet temperature; that means either warm or cold extrusion. Such a working method will, in many a point, lead to a radical dismissal of the practice used so far in extruding aluminium alloys.

The higher deformation resistance of the materials at lower billet temperatures requires, on the one hand, higher specific extrusion pressures and, on the other hand, endeavours have to be made to keep the extrusion ratio as low as possible, i.e. to extrude billets of a rather small diameter. This leads necessarily to small, quick-operating and automatically controlled presses. Extruding at lower temperatures will allow the use of lubricants, resulting in a radical transformation of the flow of material. It is to be expected that some characteristic faults of extruded products, such as extrusion defect and coarse-grained peripheral zone, may thereby be eliminated, leading at the same time to a reduction of discard. It is further to be hoped for an improvement in tolerance (dependent on the uniform shrinkage at constant emergent temperature) and of surface. No great hope must be entertained, however, regarding work hardening of cold extruded sections. The strong deformation in cold-extrusion causes more heat in the material than a single pass in cold-rolling of sheet, so that at least a strong recovery is to be expected.

By using a lubricant and a normal square die, a material flow parallel to the die surface is formed. This kind of material flow, usually found in indirect extrusion only, shows that a flow process of Type A, according to the classification of Pearson, has taken place indeed. In using a conical die, a dead-metal zone has formed along the die inlet in spite of lubrication.

With higher extrusion pressure, the lubricant film breaks down more and more and causes the material to stick to the tools. This shows most markedly in a die with a conical inlet, in agreement with the results of Wilcox and Whitton.

Dr. A. P. Green (Tube Investments Ltd.): It is fairly clear that in extrusion one can alter the process by altering frictional conditions and tool shapes, speeds of the ram, temperature of the billet, and so on. But it is quite clear that detailed control is not possible.

It seems to me that the role of the theory, just as much as the role of the experiment, is to a large extent concentrated on sorting out the important mechanisms, both mechanical and metallurgical, and not so much to produce or try to produce, a comprehensive overall description of what is happening in every part and stage of the process. The other thing that can be done, of course, is to produce very approximate theories for quantities, such as pressure and temperature, which give a guide to how to form empirical formulae in conjunction with experiment.

I think that the Paper by Wilcox and Whitton illustrates how very little theory one needs in order to produce a reasonable empirical formula based upon a well-conducted series of experiments. They did not even have to make a very good estimate of the main yield stress. To make an estimate based upon log R is obviously an approximation. It is not too bad at the higher values of the production ratio, but it is certainly in error at the low ones. In fact, they might not have been able to draw such good straight lines if they had made this correction.

There is one point on which I think the authors might have made a concession to the plasticity theory, and that was on the question of allowing for the effect of friction on the container wall in a lubricated extrusion. Here it seems to me that the pressure on the container wall should not be equated to the pressure on the extrusion ram, that one should recognize the fact that the material has a finite yield stress and deduct that from this pressure, because it seems to me that when one is pushing the ram and has a pressure of P/L, the pressure on the wall is going to be P/L in some yield stress of material which may even depend on the frictional conditions to a certain extent on the ram, because if there were friction on the back of the ram, one would presumably transmit less pressure to the wall of the container. This will make a slight difference to the coefficient of friction, which the authors calculate. In fact, it will make the coefficient of friction more constant, because at the lower extrusion pressures this has an appreciable effect, whereas at the higher extrusion pressures it makes very little difference.

On the question of the compression test and the sort of data that one wants to get from it, I would like to make a plea for somebody to pay some attention to the effect of changing strain rate throughout the test. It is not necessarily true that if one alters the strain rate during the straining process the stress follows directly the alteration of strain rate. It tends to lag somewhat behind, and, therefore, it is not always valid to have only curves at a constant strain rate. Also, presumably, if one is altering the strain rate throughout the process one may alter the temperature changes in the specimen, so that it would seem to be worth while to have a look at this sort of question more thoroughly, and also, possibly, to simulate on a plastometer the various stress strain rates which one would get in the rolling situation and to see whether one gets the same answers from that sort of direct experiment as one does out of the testing at different strain rates.

Dr. Alexander showed a slide showing what he called the adiabatic line when plotting the temperature of the billet against the reduction. He suggested that one might get at that line by means of knowledge of the extrusion pressure. But I do not think this is really adequate,

because what one is really interested in in this limit is whether any of the material will melt at all, and, therefore, one has to concentrate one's attention on this effect on the billets which are receiving the maximum amount of punishment. One wants to know, in other words, what regions of the billet are receiving the maximum amount of work rather than the mean amount of work as represented by the extrusion pressure. Presumably, the outsides of the billets, where the maximum friction and shearing occur, are the regions which reach the maximum temperature, especially at high extrusion rates. This, of course, is an argument which supports the procedure of measuring the outside temperature of the billet, as Prof. Singer has done.

Afternoon Session

Dr. R. N. Parkins (University of Durham): If we look at Fig. 2 of the first Paper by Wilcox and Whitton, we see that the pressure for direct extrusion drops below that for indirect extrusion after a certain amount of ram travel. This is rather odd when they make use of equation (4), because this equation, in effect, requires that the minimum pressure in direct extrusion shall be equal to the pressure for indirect extrusion. In fact, I am worried about the shapes of the direct curves shown in Fig. 2, because this equation involves other assumptions which are not, in fact, met. It assumes that the pressure/ram travel curve is a straight line. It is very rare in our work to have straight lines, and so I began to wonder what these coefficients of friction are which the authors calculate, and what they really mean, especially when it is borne in mind that in many cases we extrude leaving a skull in the container. There is a very little relative motion of the surface of the original billet and the container, in which case the coefficient of friction is effectively 0·5 the shear strength of the material. I wonder, therefore, whether this talk about friction has any great significance. It may be that these authors experimented without the skull and, therefore, the coefficients of friction are obtained, but even so, my point would still be valid to some extent.

They propose an equation, following Johnson, showing the relation between rate of extrusion and extrusion ratio, and they say that the equation can be extended to the higher exponential ratios. The results which interest me most are those concerned with very high extrusion ratios and with dies of 90°. The only other results of which I know which are equivalent here are those published by Pearson very many years ago with extrusion ratios of about 5, similar to those used by the present authors. If we plot Pearson's results on the Johnson basis we do not get a straight line relationship and Pearson's results lie well above the curve. One wonders why this is. I am not suggesting that one is right and the other wrong, but why is there this difference?

Pearson studied lead extruded at about 0·1 in/min., so that the conditions were likely to be much more isothermal than those in the other case. I think, in other words, that there is the possibility of an appreciable temperature rise in the I.C.I. work. It is not easy to estimate what it is from the information given, but possibly it is of the order of 40°-50° at the higher extrusion ratios. This would produce a reduction in the extrusion and would make the points at high extrusion ratios go to higher values than are shown by a straight line relationship.

The second Paper by Wilcox and Whitton interests me because of the explanations which the authors give for cracking and surface mottling. In the first place, it seems that both of these defects occur under conditions of reduced pressure; that is, they appear if the pressure falls off in the one case or in the other cases in dry conditions where the pressure is less. For example, the authors refer in one case to an extrusion ratio of 5 and a die of 90°, where cracking occurred towards the end of the extrusion and not towards the beginning.

I think that if welding is involved—that is, if there is sticking, and I assume there is a weld formed—it is reasonable to expect that this will be greater, or there is a possibility that it will be, when the pressure is high rather than low, and one wonders, especially in view of the remarks of Chadwick this morning, and the curves which showed that the surface of the die rose to melting point, and the remarks of Ursell about hot friction, which is a surface effect, whether we have not got something similar here to that which we have in hot cracking, transverse peripheral cracking. May it not be that we have very high local temperatures developed which cause cracks? These cracks could well extend not because of the frictional conditions as such, but because of the stress conditions, particularly with regard to the initial cracking, which may be a temperature effect. It may be possible to decide whether or not this is so by very careful examination of the surface. It seems to start as intergranular cracking, which is a peculiarity of the hot condition, and it may be that careful metallographic examination of surface conditions would show whether or not this is another instance of cracking being initiated by heating effect.

The reason, or one of the reasons, why I doubt some of the explanations is that I think it is true that in the extrusion of certain plastics materials it is very frequently the case that, to avoid cracking, the industry uses dies with particularly long bearing necks. Those would seem to be just the conditions which give rise to this cracking. In a crude sort of way it may correspond to the extrusion of a pressurized fluid.

I feel that there is one vast part of the subject of extrusion which is relatively untapped as yet and on which more work requires to be done—the field of unsymmetrical extrusion. Its industrial importance must be considerable, because in tube extrusion and in the extrusion of more complicated sections we have unsymmetrical flow occurring.

S. H. K. Al-Samarrai: I have tried to use the formula of Pocock and Robbins in estimating the coefficient of friction at high speed. As we increased the speed, the coefficient of friction increased. This is obviously a temperature effect. Secondly, we tried an isothermal extrusion at high speed. This was done by first of all getting normal extrusion and then having an interrupted extrusion, leaving it for a certain length of time for the heat to equalize. In this way, we were able to get consistent results whatever the speed. From 5 in. to 13 in. we obtained consistent results. For the coefficient of friction measured by straightforward extrusion, the average was about 0·057, and from the interrupted extrusion it was about 0·031. That was using graphite and alcohol. The difference is marked.

The experimental work which we have done on strain hardening is to measure the hardness and see how the hardness varies with time and with ram travel. The cross-section of the rod at a certain

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interval was taken, and the hardness taken at the middle and the edge. Although the starting hardness of the material was 14, the results all showed that the hardness rose to about 44 and then stayed constant for some time, starting to drop at the end.

We have some results which show that the hardness decreases as the extrusion speed increases, and that follows the temperature. The theoretical work of Dodeja and Bishop shows that the temperature of the outside can be 100 per cent higher than the inside, and this temperature difference may be very important in the shortening of the metal. Although when the temperature is measured it may be below the solidus line, probably at the point of leaving the die it is much higher. By the time it is measured, equalization of temperature may have already taken place.

Dr. M. T. Watkins: For aluminium of 99·5 per cent purity, temperature increases of the order of 200°C. are obtainable at the relatively low speed of 5½ in/min. In unlubricated conditions, temperatures of the order of 120°C. are obtained at the higher reductions.

If those figures are compared with those of Prof. Singer and his colleagues it will be found that they are considerably higher. It is unfortunate in many ways that a direct comparison of the results is not possible, but we have picked on one or two cases where it is possible to attempt some sort of comparison, and these comments apply particularly to the extrusion of chemical lead rod. Prof. Singer and his colleagues quote an extrusion ratio of 29, a ram speed of 10 ft/min. and a temperature of 70°C. measured on the product itself. The nearest that we come to this is an extrusion ratio of 25, a ram speed of 9 and a maximum temperature of 107°C. In all the results where we have been able to make comparisons there is this difference of roughly 30°C. between our results and those of Prof. Singer and his colleagues.

For a ram speed of 0·4 in/min., which is used in the Wilcox and Whitton Papers, there is a temperature rise of approximately 20°C. If the ram speed is increased to 34 or 35 per minute, which corresponds to the other end of the series of Prof. Singer and his colleagues, temperature increases of the order of 180°C. are achieved. These are measured at points ⅛ in. deep inside the billet and on the centre line of the slug.

With specific reference to the Papers by Prof. Singer and his colleagues, we believe that the properties, structure, surface finish and dimensions of extruded products are determined by conditions prevailing inside the container during the extrusion process. The distribution of temperature and the differences between billet, container and die are the all-important factors. The temperature of the emerging product is a consequence of all these and it cannot readily tell you what is happening inside the billet. By a series of fairly elaborate experiments you might try to follow the temperature of the product with the temperature distribution inside the billet, but this would be a lengthy and tedious business. However, as a reference point for a control system, as advocated by Prof. Singer, the temperature of the emergent product is obviously satisfactory, because he has demonstrated this in his Papers.

Measuring the temperature at a distance of 2 in. from the die is probably quite satisfactory at the higher ram speeds, but one wonders what error is introduced by quoting values for ram speeds of the order of 1 in/min., because the distance of 2 in. must be quite important at this speed. The temperature increases obtained in the extrusion of lead, except at the higher rates of production, are constant throughout the operation, which suggests that the effects of conduction are small, the major loss of heat occurring by transport in the product.

R. Davies: Referring to the Paper by Arnold and Parker, I think that with the advent of impact extrusion and higher extrusion velocities we need curves at a greater strain-rate per second. I wonder whether anyone has any experience of higher strain rates and the effect on deformation. From looking at the curves, it appears that the difference becomes less as the strain rate increases.

Dr. P. B. A. Willis (Imperial Aluminium Company): The Paper by Arnold and Parker seems to me to be somewhat irrelevant to a discussion devoted specifically to extrusion. I suspect that these authors themselves think this, from their reference to hot rolling. In this context, their work is very interesting, and it is potentially a most valuable technique which they offer; but any application of the work reported, at least to the hot extrusion of aluminium alloys, strikes me as dubious, in the first place because their decrements correspond to extrusion ratios of only 2:1 at the most, compared to 15:1 to 200:1 in extruding practice. Secondly, friction figures have been determined experimentally and corrected for mathematically, but aluminium extrusion is certainly anything but friction-free. Thirdly, I have not worked out typical extrusion strain rates from the formula, but the strain rates used in the work of these authors seem to me to be very high.

The two Papers by Wilcox and Whitton, unfortunately, do not mean much to me in terms of production, or at least, not yet; but I cannot resist mentioning that it is very nice to have confirmation that flat dies require the lowest maximum pressure, a principle known and used in production practice. In the same Paper they have a very ingenious interpretation of the fir tree effect. A careful study of their photographs gives me the impression that there is a flat non-detected length between each branch (as it were) of the fir tree. This corresponds to the die land reported in their first Paper, and seems to bear out their contention that the first attack results from galling on the die bearing. Speed of cracking is not obviously relatable in my experience to the die land, and, as the fir tree effect cannot arise from an extremely high surface temperature, I wonder whether the authors would like to give an explanation of speed cracking.

Dr. Parkins mentioned the use of long bearing ends in industrial practice. That is not true of production practice for aluminium, where the trend is towards minimum bearing lengths for decreased pressure and highest quality. If we could support an infinitely thin knife-edge of adequate wear resistance we should use it.

In the Paper by Singer and Coakham they mention the difference between metals of different thermal conductivities and mechanical properties. Super-purity aluminium and commercial aluminium have similar conductivity but different mechanical properties. There is another difference which may be of overriding importance, and that is the nature of the extrusion: deformation characteristics. Commercial purity aluminium would certainly extrude under Pearson type C extrusion conditions. From the Paper, I get the impression that there is an attempt to obtain type A extrusion with the super-pure, but that probably failed.

With reference to what these authors say with regard to the energy liberated by friction and the energy of deformation, Pearson, quoting a number of references, mentions something like a 45 per cent difference in the energy required to deform in direct, compared with inverted extrusion, and this 45 per cent difference can presumably only be the difference in moving the billet along the container. This 45 per cent is not something which one can dismiss lightly.

I found the results reported by Singer and Coakham on the study of commercial purity aluminium at 260°C. and 400°C., Figs. 5 and 6 of their Paper, most thought-provoking. I wish that the authors had extended this aspect of their work to more starting temperatures and by using a higher ratio. In their Paper they mention the use of a higher ratio, but do not give any results with their restricted ram speeds to get extrusion speeds more closely approaching those in industry. Using the results presented by their Figs. 5 and 6, at ram speeds of 10 and 30 in/min., it is possible to present their results at any stage of extrusion in empirical form, which is of considerable interest to me. If we plot emergent temperature against what I will call billet temperature — the authors call it starting temperature—at the two

Mrs. S. S. Chatwin, Prof. R. W. K. Honeycombe, Dr. and Mrs. G. L. J. Bailey

ram speeds involved, we get four points. We can join those points by straight lines, though it is unlikely that it is a straight line; it is probably a logarithmic relationship. Assuming, however, that there is a straight line connection of that kind and that this work were extended, I can visualize that we would eventually get a number of isospeed lines tapering towards a fixed point—whether they would reach it I do not know. We could put in a line for the emergent temperature corresponding to defective material, because as a production man I want to get material out as fast as possible and free from defects. Such a line may well be anything but straight, because of pressure effects from the effect of varying billet temperatures.

Finally, Singer and Coakham mention temperature control. This is very interesting work indeed, from the production point of view, and I wonder whether it has not cut a lot of ground from under the feet of those who are trying to define mathematical relationships which eventually we could use in production to get maximum production with maximum surface quality. I wonder, therefore, whether some of the effort which is at present being put into this could not be devoted to the development of a really satisfactory pyrometric device for measuring emergent billet temperature. We shall then try to use it in production conditions and we may be able to reach results very quickly.

Mr. Pugh: Davies has referred to strain rate. Some work was done by C. I. Taylor during the war to determine the effect of rate of strain in cables. The rate of strain involved was of the order of 10^4/sec. and the general result was that at this rate the yield stress in mild steel went up by a factor of 3, which is very considerable, whereas in the case of steels such as Ni-Cr steels or steels in the region of 120 tons/in^2, the increase was very small indeed.

My comments will be confined to the two Papers by Wilcox and Whitton. These authors, in obtaining their mean flow at yield stress, take a purely arbitrary definition of the strain, log.R. In many ways I feel that they might have done rather better to follow more closely Prof. Johnson's work on lead to get a formula for the plastic strain. He obtained an effective strain of $0{\cdot}8 + 1{\cdot}5$ log.R, and that equals ϵ_M. In his work he looks up the stress/strain curve done at the same speed and averages yield stress from 0 up to this particular value ϵ_M. As these authors have not done this, they have no constants which are appropriate, and that is why they have taken as the mean strain the value of the yield stress at a value of strain equal to log.R.

I would add that if we look at their Fig. 8 we find that there is surprising agreement between their results and Johnson's formula. The probable explanation of this is, however, that the value of the yield stress obtained in the two methods is very little different, particularly at large strains. Where the stress/strain curve is more or less flat, there is unlikely to be much difference between the two. A word of warning is necessary, however; the equation of Wilcox and Whitton is likely to fall down at very small reductions.

Equation (3) in the first Paper by Wilcox and Whitton may be a little arbitrary. I say this because we have looked at our own data in relation to this equation and find there are distributions which are quite large.

Experiments in the extrusion of lead show that it is possible to get identical characteristics for forward and backward extrusion.

Some results which generally confirm the results of Wilcox and Whitton, were obtained with a sharp-ended die and aluminium. The reason for this is that the slug is a cylinder, and when the cylinder is slipped in the die to start with, large stresses are set up, and in a short time there is a pick-up between the die and the slug. It would be useful if the authors had given in the Paper some more information about the state of their dies as a result. What I have been saying is borne out by the fact that if one uses cylindrical dies and no slugs one can produce the opposite effect.

I think that, by and large, I am in agreement with the suggested mechanism put forward by Wilcox and Whitton, but I disagree with Dr. Alexander when he says that this is the way to deal with it, because with some other alloys we get no fir tree effect at all; though we do get, for an angle bigger than 90°, a sort of stick-slip action, this is not accompanied by a fir tree effect.

AUTHORS' REPLIES

Prof. A. R. E. Singer: Dr. Alexander commented on the curve which we obtained for the emergent temperature of a high purity aluminium. The question was why, in the case of high purity aluminium, does the slope of the curve continue upwards in the way shown. I can confirm what he suggested, that this is not primarily concerned with the strain-hardening of the aluminium itself. The strain-hardening of the aluminium undoubtedly has a small effect of increasing the temperature as the travel of the ram increases, because in effect it increases the yield stress. The major effect, however, is undoubtedly the fact that first of all, in the case of aluminium we have a material which is of high thermal conductivity, and, secondly, we are dealing with finite billet length, so that towards the end of the ram travel there is necessarily very limited conduction back of heat, because the heat has not anywhere to go or can only go into the boundary between the end of the billet and the ram itself. Those are the two main features which cause the curve to go up in that kind of way.

He also commented on the possibility of obtaining this sort of curve by a theoretical analysis of heat flow. I think that Al-Samarrai mentioned that we are currently undertaking this sort of work

Mr. and Mrs. A. R. Powell, Mr. S. S. Chatwin, Mrs. E. C. Rhodes

Prof. and Mrs. J. Nutting and guests

and hope to get a reasonable solution, which at the present time seems to show this general trend.

We have found that it is possible to produce the programmes which can be derived from the various emergent temperature/travel curves, such as we have shown for aluminium, and to evaluate manually those programmes without being able to produce an isothermal extrusion. The difficulty is mainly due to the fact that there is an enormous drop in speed at the commencement of extrusion, and, as we have to do the work manually, there is always a slight difference between the ideal and what we get.

The main feature, however, which comes out of this Paper is that by altering ram speeds it is possible to alter very significantly the emergent temperatures of extrusion; but I would say at this juncture that I am opposed in principle to preselected speed programmes, and I think we ought to aim, so far as we can, at some kind of control system whereby we feed back information derived from the temperature of the emergent extrusion and use a closed-loop control scheme of that sort. Perhaps a preselected programme is a very necessary first step in that direction, but we should keep clearly in mind the final objective of using a true closed-loop automatic control system. I support what was said by Dr. Willis, that a little effort should be diverted to the development of radiation pyrometers for getting the temperature of extrusion.

I confirm Dr. Bloch's belief that the general trend in extrusion, particularly with aluminium alloys, is to try to raise speeds and lower initial billet temperatures. I think that we are far too primitive and that much more could be done if we set about it in the right way. I differ from him in some respects; I believe, for instance, that we should consider the possibility of using intermediate starting billet temperatures and extrude very rapidly, thus raising the emergent temperature to the level desired. This might aggravate the lubrication problems but it would reduce some of that pressure which at present forms a barrier.

Dr. Watkins made some comments in connection with the work of N.E.L. on extruded aluminium billets. It is true that this work at N.E.L. is the counterpart of the work which we have been doing, but we must remember that the thermocouples were fairly large when compared with the billets themselves, which were mainly about 1 in. in diameter. Consequently, when the thermocouples eventually got into the region of the die zone, and then the die orifice, effectively what was being done was to extrude a very small tube, and, though a tube was not in fact formed, when freezing took place over the thermocouple sheath the effect was that the extrusion ratio was probably very much higher than it would be otherwise. If this were an important factor it could easily raise the temperatures to a value, say, 30° C. higher than those which we measured. This is necessarily an estimation, but it is a probability which deserves consideration.

Sir Harry and Lady Melville

His second point was that we measured the surface temperature at a distance of about 2 in. from the die. It is a very simple matter for us to plot the emergent temperature on the thermocouple against the die. We know very well from the speed of extrusion how much time has elapsed between the moment it emerges from the die and our taking the temperature, and it is easy to extrapolate backwards, assuming that there was a uniform temperature across the cross-sectional area. The result was that the difference was fractional, a difference of a fraction of a degree, or of not more than 1-2°. It was quite inconsiderable for our work and it became at all appreciable only at the very lowest speeds. Moreover, at the very low speeds and lowest reductions, when the time interval was greatest, the mass of the extrusion, the cross-section, was greater and, therefore, the rate of cooling was lower, so that the two offset each other and the error was so small as to have no detrimental effect on the experimental results.

Prof. P. W. Whitton: There has been a good deal of discussion on why we took our wide bar at log. eR as opposed to Johnson's $y = A + B$ log. R. The simple explanation is this. You have seen the errors which may occur in producing yield-stress data at about 80 per cent reduction, but it is at about 90 per cent reduction, and in many cases 99 per cent, that we are interested in the yield stress data. We have to face the fact that no one has yet produced a yield-stress curve for a reduction which goes up to 99 per cent. We have to stop short perhaps at 80 per cent, though Professor Johnson did get up to 95 per cent. What we do, therefore, is really an academic point. In any case, we say in our Paper that the difference is ± 6 per cent or 7 per cent.

Dr. Parkins mentioned that in one or two of our diagrams, and particularly Fig. 2 of our first Paper, the direct pressure fell below the inverted. The simple explanation is that with the inverted extrusion it was purely the rate of flow, but for the direct it got below because a dead metal zone, or, if you like, a pseudo dead metal zone, formed, so that this is for us not particularly frightening.

He also mentioned that, to some extent, our work complemented that of Johnson. We go beyond the limits which Johnson set in his work because we wanted to get into the range of interest to industry. Johnson stopped at a ratio of 17 and dealt with lead and super-purity aluminium. We deal with super-purity aluminium, but we go up to a ratio of 150, and we apply that to aluminium alloys and copper, in which we are interested.

There seems to be a difference of opinion on the cause of the fir tree defect. We wondered whether that which occurs cold is possibly caused by the same reason, that is friction, as when there is speed cracking hot. It seems that Pugh and Dr. Willis agree with our explanation of the defect, whereas Dr. Parkins does not. Dr. Willis said that he had examined the die land length and it appeared to correspond to the length on our pictures of the part which had stuck. He knows that he should have gone deeper into it than that, because the specimens were available almost in the office next door, so that if all he did was to examine the photographs I have no comments to make!

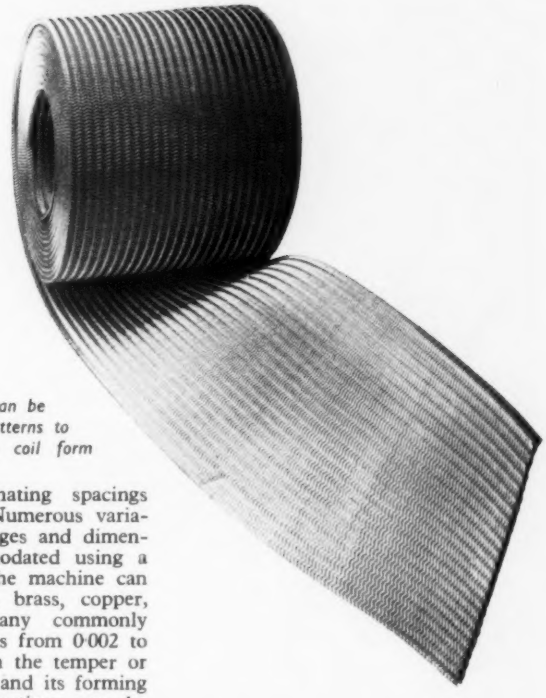
Dr. Pugh made the point that it was possible to adjust the pressure from the conical dies which were used, and this is true; nevertheless, we felt that we wanted to know what happened in the case of a simple conical die.

He pointed out that our friction may well have been higher than in work done by him and his colleagues at N.E.L. I think that that is possible, but what is important is that we have defined our lubrication conditions and they are not the same as those used at N.E.L. and, therefore, it is not surprising that there may be a difference. A variation of the coefficient of friction from 0·01 to 0·02 would cover the range he mentioned.

The chairman then brought the proceedings to a close.

Folded Metal

VARIETY OF APPLICATIONS FOR CORRUGATED MATERIALS



Strip up to 36 in. wide can be folded in a variety of patterns to produce folded metal in coil form

FOLDED metal—a form of corrugated metal with wide potentialities is being produced in the U.S.A. It is formed by dies moving in both vertical and horizontal planes; simultaneous offsetting, perforating, slotting or lancing are possible, so that an unlimited variety of patterns can be obtained. The method of forming overcomes corrugation problems such as size limitations, pattern variations, tolerances, and the high cost of tooling and setting up.

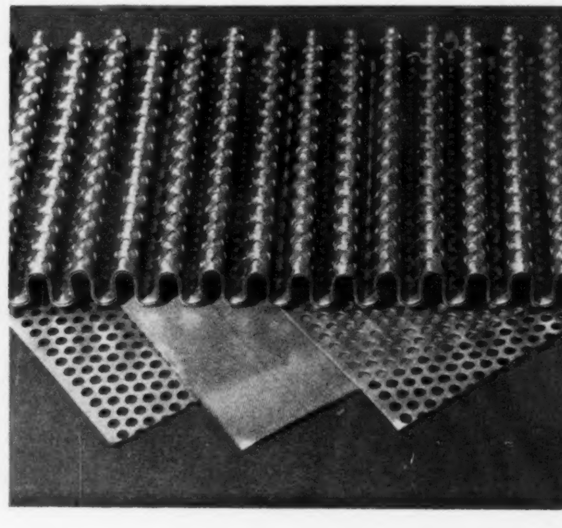
The method of forming was developed by the Twin Coach Company, Buffalo 25, New York. This firm specializes in the design, development and production of lightweight ferrous and non-ferrous metal structures for use in aircraft, missiles and vehicles. In the forming process, the metal is literally folded, without any drawing or stretching action. The horizontal and vertical movements of the forming dies are controlled by cams; corrugations of varying depths can be made without changing either cams or dies. Furthermore, the horizontal stroke of the machine can be varied to give corrugations of alternating spacings along the material. Numerous variations in materials, gauges and dimensions can be accommodated using a single set of dies. The machine can deal with aluminium, brass, copper, stainless steel and any commonly formed alloy, in gauges from 0·002 to 0·030 in., depending on the temper or hardness of the metal and its forming characteristics. Corrugations can be formed with depths from 0·060 in. to 0·500 in., with a tolerance of ±0·001 in. Present equipment will take continuous lengths of stock in widths of up to 36 in., but greater widths could be accommodated on specially built machines. A useful feature is that several different patterns can be produced across the stock simultaneously by suitable choice of dies.

Using coiled stock, corrugation is performed at a rate of 2 to 9 ft/min., depending on the fin spacing. The machine is relatively inexpensive, and the dies can be used for an average of 1,000 hr. before the need for replacement. Folded metal can be sheared, rolled and stretched into various shapes, and can be embossed on standard presses.

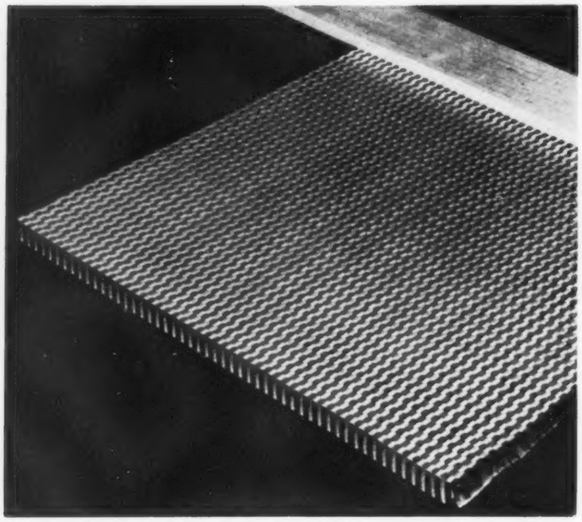
Painted or pre-coated metal can be run through the forming machine

Left—Folded metal emerging from one of the forming machines

Below—Composite materials may be folded, opening up possibilities for a variety of applications



Folded metal can be sheared, rolled or stretched, or embossed on standard presses



A wide variety of patterns and forms can be produced by the folding technique

without damaging the surface or spoiling its appearance. Furthermore, the machine is equally suitable for corrugating plastics or cardboard.

The attractive appearance of folded metal suggests many applications as screens, ventilation grilles and curtain walls in contemporary building construction. Similarly, the material may be used to enhance the appearance of space heaters and electronic equipment. As a heat-exchange surface, folded metal gives improved efficiency and a saving in space. In the electronics field, an important use is in the construction of both flexible and rigid wave-guides for very high frequency radio-waves. Many other uses are likely to be developed when the full scope of the forming process is appreciated.

Men and Metals

It was announced last week that the Council of Scientific and Industrial Research has approved the appointment of **Dr. C. J. Jackson,** O.B.E., M.Sc., to be chairman of the Water Pollution Research Board for the period April 1, 1961, to March 31, 1966. **Mr. E. Etheridge,** B.Sc., F.R.I.C., a member of the Central Technical Office of Courtaulds Ltd., has been appointed a member of the Research Board for four years from April 1 last.

Three new appointments have been announced by Darchem Engineering Limited, a member of the Darlington Chemicals Group. **Mr. A. B. Miles,** who has been with the company for six years, becomes chief engineer. **Mr. F. Meadows** is to be chief draughtsman; he joined the company in 1955. **Mr. D. A. Rowlett,** M.Sc., has been appointed manager of the Rostenit Division. He joined the company in 1960 from the Standard Telephones and Cables Company, where he was assistant chief metallurgist.

After 52 years with George Cohen Sons and Company Limited, **Mr. James Brennan,** shipping manager, has retired.

In succession to **Mr. G. J. B. Williams,** who is now to concentrate on the company's reorganization and sales development, **Mr. E. B. Bishop** has been appointed secretary of Metal Cleaning Limited, a member of the Castrol group of companies. Both Mr. Bishop and Mr. Williams are directors of Metal Cleaning Limited.

At the Annual General Meeting of the Birmingham Local Section of the Institute of Metals, held last week, **Dr. I. G. Slater** was elected chairman and the following members were elected to the positions of officers and committee:—**Mr. S. S. Chatwin,** chairman-elect; **Mr. L. G. Tottle,** hon. secretary; **Mr. R. Chadwick,** hon. treasurer; **Mr. L. H. Fairbank,** assistant hon. secretary. The committee is composed of the following:—**Mr. L. G. Beresford, Mr. E. J. Bradbury, Mr. F. G. Haynes, Prof. A. D. McQuillan, Mr. H. J. Miller** and **Dr. N. Swindells.**

In succession to **Lieut.-Col. S. C. Guillan,** T.D., who retires at the end of this month, **Major R. E. Moore** has been appointed secretary of the Institute of Metals.

After holding the position of chairman of the Nobel Division of Imperial Chemical Industries Limited since 1955, **Dr. James Craik** has retired and is succeeded by **Dr. John M. Holm** as chairman. Other appointments in the Division are announced as follows:— **Dr. A. D. Lees** to be joint managing director, **Dr. J. Bell** to be production director, **Mr. J. A. Lofthouse** to be engineering and technical director, with a seat on the board, and **Dr. J. S. Flanders,** another new director, to be the division's home sales control and technical service director.

Two new directors have been announced by Alcan Industries Limited. They are **Mr. A. A. Bruneau** and **Mr. R. J. Moyse.** Appointed chief financial officer and treasurer last year, Mr. Moyse joined the organization in 1951. Mr. Bruneau joined Aluminium Limited in 1949 and became secretary of Northern Aluminium last year.

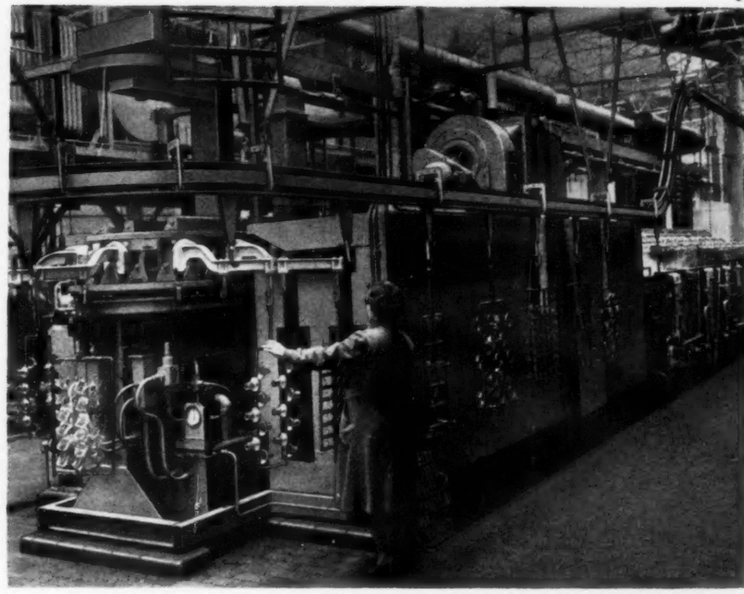
News from W. Williams and Sons (Holdings) Limited is to the effect that **Mr. D. L. Roper** has been appointed group sales manager to the company and will be responsible for all the sales activities of Williams Alexandra Foundry Limited, Dialoy Limited, and Bronze Smelters Limited.

The two assistant technical directors of the Aluminium Development Association, **Mr. J. C. Bailey,** F.I.M., and **Mr. F. L. Stafford,** have just left for an extensive tour of Canada and the U.S.A. They will visit Aluminium Limited, Montreal, and Aluminium Laboratories Limited at Kingston, followed by visits to each of the principal American aluminium producers, and, in particular, their research and development departments.

Plating Shop Layout and Installation

By

C. R. DARBY



[Courtesy The Ever Ready Co. (Gt. Britain) Ltd.

Fig. 2—Automatic plant for bright nickel and chrome plating showing conveyor for transferring jigs to and from plant.

In the preparation of designs for a plating shop or cleaning line, several factors affect the final choice of equipment and its arrangement within the space available. Some of these factors are discussed in this article, which is based on a talk given by the author to the Midlands Branch of the Institute of Metal Finishing. The first part, which appears here, deals with plant layout, the second part will cover the planning and installation of the necessary services.

IN the design and engineering of a new plating shop, the four major stages may be listed as: (1) determining the various process sequences for the range of components and the finishes required; (2) deciding on plant requirements; (3) the layout of the plant in the area available; (4) the planning and installation of the services.

Plant requirements will vary considerably and will depend upon:—capital available; production quantities, variety of finishes; size of components; the degree of automation required—the economy of fully automatic equipment versus the flexibility of semi-automatic working; the area available—this will, in certain cases, limit the type of plant it is possible to install.

Plating shop layouts fall into one or more of the following general groups: automatic plants, with or without automatic loading and unloading; mechanized plants utilizing overhead runways and hoists; manual plants where the work is transported from tank to tank by hand; semi-automatic plating units fed by one of the above three methods.

These broad classifications hold good whether the plant requirements are for vat plating, barrel plating, or a combination of these.

In considering the layout of these four types of equipment it is proposed to deal with the automatic plating plant briefly, and at more length with the other types where the problem of planning the layout is more complicated.

Automatic Plant

An automatic plant is a complete machine, and the problem of layout is merely the siting of the ancillary equipment, usually alongside the plant, the provision of the necessary services and the integration of the equipment into the production flow.

The automatic plant can be treated as a machine tool—it may be installed in the production line, or it may be in the plating shop with other plating equipment. In this latter case, it can be considered as one item in the layout of the larger area.

A typical layout incorporating two return type automatic plating plants is shown in Fig. 1. The upper automatic

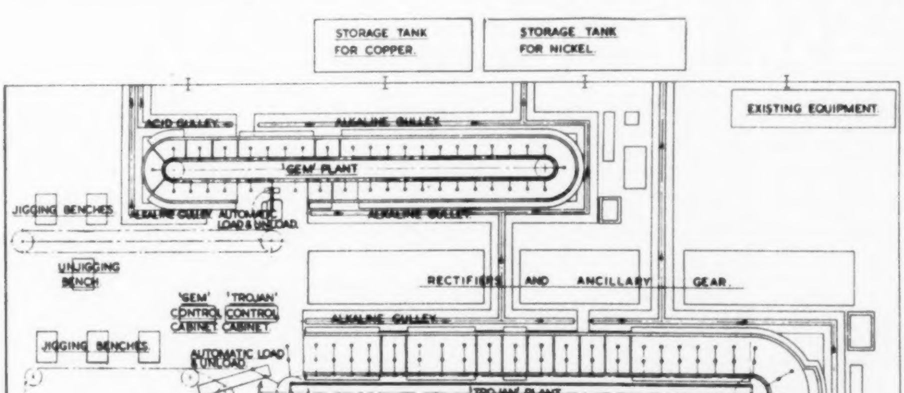


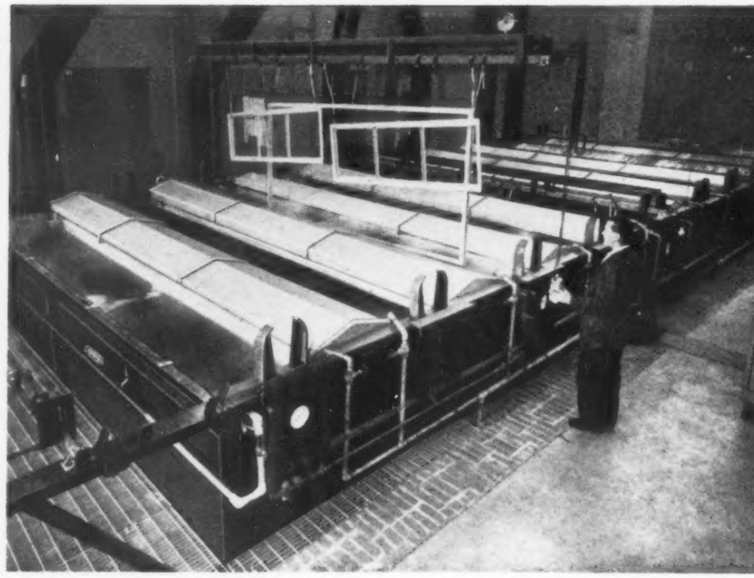
Fig. 1—Layout for two automatic plants, one for copper, the other for bright nickel and chrome. The use of automatic load and unload equipment is illustrated.

[Courtesy J. Billam Ltd.

unit is of the single line return type with the loading and unloading position on the side of the plant, and the lower automatic is a two line unit with the loading and unloading position at the end of the plant. The rectifiers, filters and rotary air pumps are positioned on the floor between the two plating units, and the exhaust fans are mounted on platforms above the remainder of the ancillary equipment. The layout shows how each unit is fed from a conveyor. In this example, the plating units are loaded and unloaded automatically, enabling the work to be jigged some distance from the plating units. A further conveyor is included to transfer the processed work to the packing department.

The loading and unloading end of a two-line return type automatic plating plant is shown in Fig. 2, which also illustrates the use of shop conveyors. On this installation, the transfer of jigs between the shop conveyor and the plant is carried out manually.

The plants illustrated are of the return type, but for larger outputs "In Line" units can be employed with loading and unloading at opposite ends.



[Courtesy Henry Hope and Sons Ltd.
Fig. 3—Semi-automatic plant for the anodizing of architectural fittings.

Mechanized Plant

Under this heading are included plants utilizing overhead runways and hoists for transferring the components from tank to tank. The hoists or travelling cranes employed, whilst generally incorporating electrically operated lift and travel, are usually manually controlled.

These plants are widely used for barrel plating and are often described as being semi-automatic. For vat plating, mechanized installations of this type are very suitable for the processing of large or heavy components and for use where it is required to mechanize handling, but where, due to the variety of the finishes required and variation in plating times, it is not practicable to install fully automatic equipment.

Mechanized plating plants for barrel and vat plating can be laid out in a single line or in a "U" shaped formation.

A mechanized installation for the anodizing of architectural fittings is illustrated in Fig. 3. The tanks are laid out in a single line, sideways on, and the work to be processed is hung from specially designed work bars. The loading stand can be seen on the right-hand side. The work bars are transported from tank to tank by means of an overhead gantry which is electrically operated and manually controlled. The processed work is finally unloaded at an unloading station; in this instance at the far end of the plant. Handling is thus reduced to a minimum.

After transfer from one process tank to the next, the gantry bridge is disconnected from the work bar, leaving the work bar on the tank while the work is being processed. This permits several loads of work to be processed on the plant at the same time.

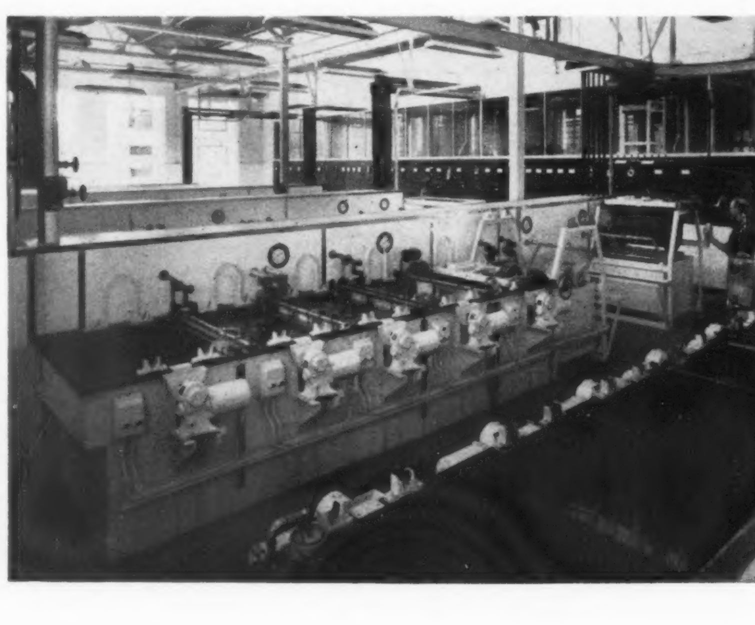
With this type of layout, a number of features can be incorporated to simplify operation and ensure that the plating conforms to the required specification. It can be so arranged that the descent of the work into the vat will switch on the rectifier, voltage and current being then raised and adjusted automatically. A system of coloured lights can be fitted to indicate the stage the process has reached; and locking devices incorporated to make it impossible for the work to be lifted out until the completion of the processing cycle.

It is also possible to have this type of layout as a return system by the incorporation of a special hoist transfer unit at either end of the plant.

A typical barrel plating plant is shown in Fig. 4. This type of mechanized unit is in widespread use today. Plant can be laid out in two lines as a return type unit as shown in the illustration, or in a single straight line. The ancillary gear is usually sited at the rear of the tanks, i.e. away from the operating gangway.

From the layout point of view, the advantage of a "U"-shaped layout is that the carrier frame or barrel is returned to the entry end of the plant on the completion of the plating cycle,

Fig. 4—Submatic plant for barrel zinc plating showing overhead hoist for transferring barrels.
[Courtesy Humber Ltd.

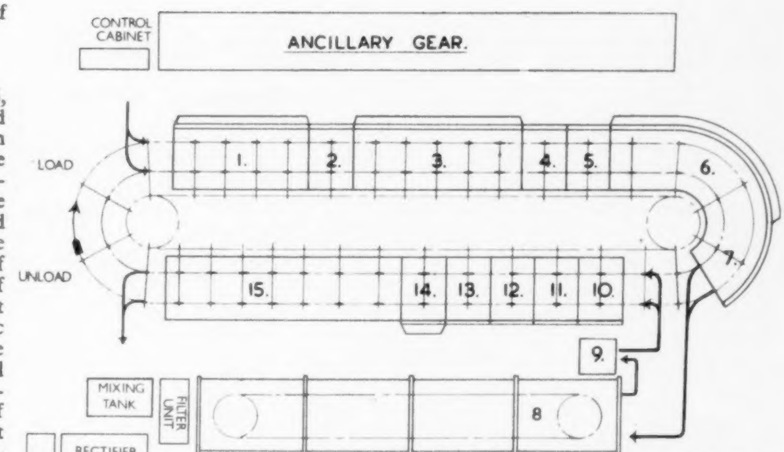


ready to commence the sequence of operations again.

Semi-Automatic Unit

A typical layout is shown in Fig. 5, in which a semi-automatic unit is used for the actual plating operation and an automatic plant is employed for the initial cleaning and final swilling operations. A similar layout could be adopted for a manual or mechanized installation, with the final swilling line as shown, or on the opposite side of the semi-automatic unit. This type of installation, utilizing an automatic plant in conjunction with a semi-automatic unit is particularly useful where the plating time may have to be varied considerably to meet differing specification requirements. Typical layouts of this pattern are: an automatic bright nickel and chrome plant with a proportion of the output being off-loaded for copper plating and then reloaded on to the automatic plant for nickel and chromium plating; and an automatic cleaning and chrome plating unit with a semi-automatic bright nickel unit.

"In-line" semi-automatic units are also available for use where the load and unload stations on the unit are required to be at opposite ends.



1—Anodax hot electrolytic clean. 2—Cold swill. 3—50 per cent hydrochloric acid 4—Cold swill. 5—Cold swill. 6—Klenewell. 7—Cold swill. 8—Rotamatic Kadamax bright cadmium. 9—Dragout. 10—Cold swill. 11—Kadip bright dip. 12—Cold swill. 13—Dichromatic dip. 14—Warm swill. 15—Drying oven.

Fig. 5—Layout showing the use of an automatic plant for cleaning and final passivation and drying with a Rotamatic plant for cadmium plating.

Manual Plant

With a manual plant, the layout requires careful consideration as, instead of one unit or a collection of tanks virtually forming a single unit, with the equipment dictating the area and layout required, there are a very considerable number of individual tanks. Manual plant layout can be further complicated by the fact that, in many cases, a number of the tanks, particularly cleaners and swills, will be common for different production sequences.

The area allocated, its size and shape, the position of stanchions and other obstacles, the relationship with the rest of the factory, particularly the work flow to and from the shop, all have a large bearing on the type of layout ultimately decided upon.

Furthermore, the positioning of drains from the tanks, fume and steam extraction, pipework services and busbars may present problems from the installation point of view and, therefore, have an effect on the choice of layout.

The problem facing the planner is to group the vats so as to give the best production flow for the various process sequences with the minimum operator

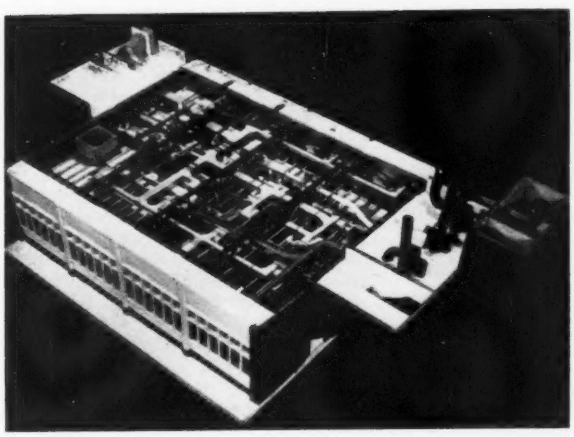


Fig. 6—Model of plating shop showing services in false suspended ceiling

[*Courtesy Rank Precision Industries Ltd.*

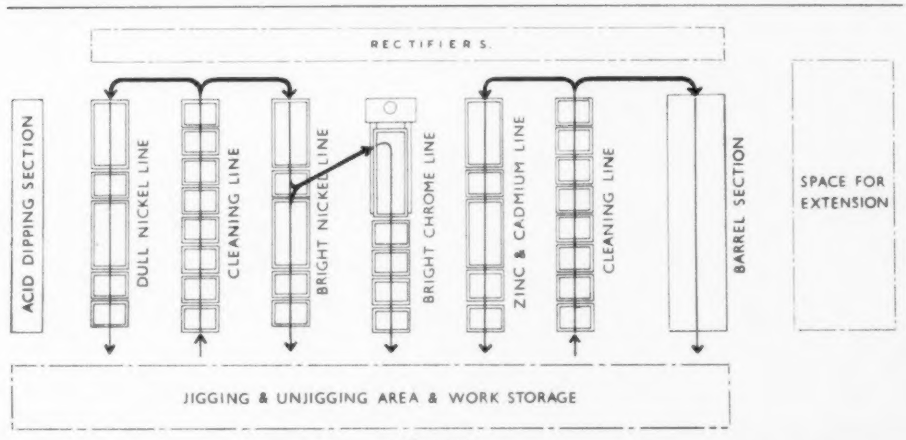


Fig. 7—Layout of plating shop showing the loop system of work flow.

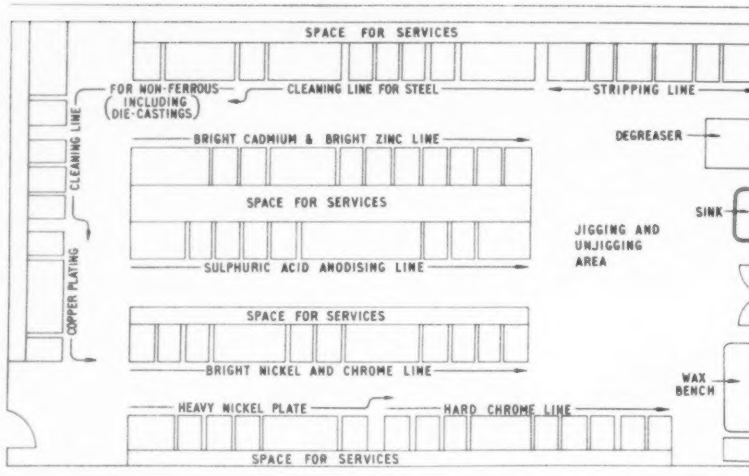


Fig. 8—Arrangement of 'L'-shaped cleaning line

fatigue. It is usual to draw up a plan of the area, marking the stanchions and other fixtures, and prepare cut-outs to the same scale in cardboard to represent the plan of each individual item of equipment. The optimum position of the vats is found, using the cut-outs, so that the process sequence flows naturally from one vat to the next with the minimum walking distance for the operator.

For large projects where special features are incorporated, such as the location of the services in a special service area, a three dimensional model can also be prepared.

A model which was built prior to the installation of a new plating plant is shown in Fig. 6. The main problem in this particular instance was the siting of the services. Due to ground conditions and also the cost involved, the installation of underground services was not considered practicable.

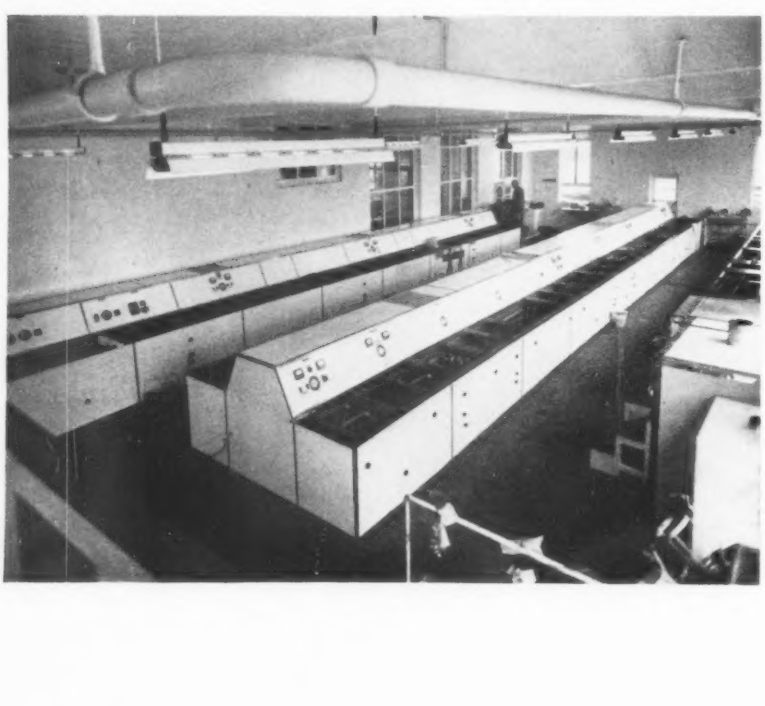
To provide a ground floor area free from stanchions, the building was constructed with lattice girders between the first floor and the ground floor. The depth of the lattice girders was approximately 4 ft. 6 in., and this depth, between the first floor and the ground floor, was used to form a false ceiling space. Horizontal runs of ventilation and exhaust ducting, the air, gas and water pipes and the electric feeds and busbars were all housed in this false ceiling. The rectifiers and ventilating fans were installed on the first floor so that they were isolated from dust and corrosive fumes.

Where possible, the work should progress in a loop, so that when the work is completed the jig is ready for the next batch of components. Fig. 7 illustrates the loop system applied to a general plating shop.

The number of cleaning and plating lines will depend upon output requirements and space available. The length of the individual lines of tanks will depend upon the length of the building. Depending on these two factors, additional plating tanks may be sited on the end of each line (the end remote from the jigging and unjigging area). In this case, the grouping of the tanks should be arranged so that the plating tanks which are used the least are sited furthest away from the jigging and unjigging area.

This type of layout has an advantage in that a return type automatic plant or a return type mechanized barrel installation could be incorporated in the shop without affecting the overall flow pattern. The work storage, jigging and unjigging area can extend the full width of the plant or, alternatively, the work could be jigged and unjigged separately and a conveyor run the whole length of the shop to return the empty jigs to the start of the line.

Fig. 9—Manual plating plant for experimental and small scale production
[Courtesy S. Smith & Sons (England) Ltd.



Depending on the type of installation required, lines of tanks may be positioned individually, as shown in Fig. 7, or pairs of lines may be sited back to back.

Typical layouts of this pattern, for the smaller manufacturer, are: one cleaning line feeding one plating line, one cleaning line feeding two or more plating lines, or the case of two separate cleaning lines feeding one common plating line sited between them, for example the hard chrome plating of steel and aluminium components.

Where there is one common cleaning line, this can be arranged in an "L" formation feeding two or three plating lines (Fig. 8). The plating shop is then laid out on a circular flow basis so that the shortest time cycle work has the shortest work route.

The other basic plan which can be followed is for the tanks to be arranged in a straight line with the "work-in" and "work-out" areas at opposite ends.

For large-scale production, tanks can be arranged in line, sideways on as indicated in Fig. 9. The work rods are extended beyond the ends of the tanks, and two operators, walking either side of the line, transport the rods through the various processes. This type of layout has been successfully used by a number of operators for nickel and chrome plating. It gives good production flow, takes up a minimum floor space, is cheaper and more flexible than an automatic.

The straight line type layout can also be used for plant with a relatively small output where, due to the length of the building, the work has to flow in long lines. The cleaning cycles are arranged together on each line, followed by the plating processes, with space between the sections. The break in the lines enables the operator to interchange between lines after the cleaning stage, if necessary.

(To be continued)

Industrial News *Home and Overseas*

Quality Determination

A new aid to quality determination in structural materials has been introduced into the U.K. by **Aveley Electric Limited**. The E-G meter manufactured by Kretz allows rapid and repeatable measurements of the dynamic modulus of elasticity (E) and the torsional modulus (G) of solids such as metal, concrete rock, plastics, wood, coal, ceramics and other rigid materials.

This wide range of applications by the E-G meter is obtained by a simple and rapid operation, whilst the sharp discrimination of the instrument gives repeatable measurements within 0·5 per cent.

The dials are directly calibrated in tons/cm^2 and 16s/in^2. The provision for the use of five calibration units and push-button selection of ranges greatly speeds up the testing of a large number of samples. The 10 in. long slide-rule dial carries a calibrated scale for the common materials, and extra scales for special material. Accuracy of the instrument is guaranteed by a built-in quartz crystal controlled oscillator, providing check points on the dial.

The equipment is reliable and self-calibrating, and is equipped with a pulse-transmitting test-probe and a mounted adjustable receiving probe to ensure accurate application to the test sample. Construction of the instrument is extremely robust and it is suitable for portable use.

Italian Copper Statistics

Italian imports of crude copper for refining in 1960 were 15,988·6 metric tons valued at 6,675,146,000 lire, of which 60·9 metric tons, valued at 25,016,000 lire, were imported temporarily, according to figures released by the Central Statistical Institute. The principal suppliers were the Federation of Rhodesia and Nyasaland with 7,860·8 metric tons, South Africa with 3,494·7, Chile 1,940·8, and the U.S. 2,184·5 metric tons.

Imports of refined copper in slabs, ingots, plates, etc., totalled 176,502·4 metric tons, valued at 71,867,022,000 lire, of which 19,864·4 metric tons, valued at 8,492,027,000 were imported temporarily. The principal sources of supply were: Belgium / Luxembourg 4,889·3 metric tons; France 6,255·9; United Kingdom 11,065·8; Congo Republic 33,654·5; Rhodesia and Nyasaland 29,039·6; South Africa 9,478·7; Chile 26,285·7; Canada 2,264·0; and the United States 47,257·1 metric tons.

Selling Aluminium

In the current (April) issue of *Design*, the monthly publication of the **Council of Industrial Design,** several pages are devoted to the selling and public relations programmes of Alcoa, the Aluminum Company of America.

Under the title of "Selling Aluminium: The New Way", an article discusses these programmes and presents a number of excellent illustrations showing the trend of design as used in the company's publicity organs, etc.

Non-Destructive Testing

All who are concerned with engineering inspection and non-destructive testing will be interested in a national conference which is to be held at Oxford in September this year, to discuss the function of management in relation to inspection, the economics of inspection and non-destructive testing, and the recruitment, education and training of inspection staffs.

This conference is being planned at the request of the Joint Committee of Materials and their Testing and the British National Committee for Non-Destructive Testing. It is being organized jointly by the **Institution of Engineering Inspection** and the **Society of Non-Destructive Examination.** The speakers invited are all closely associated with their subjects and have wide experience in the fields concerned. Sessions will be arranged to allow ample time for discussion.

In view of the wide interest already expressed by industry, learned societies and the teaching profession, residential accommodation at Queen's College and New College, Oxford, has been reserved over the period September 5 to 8. The total cost, including conference fee, accommodation and all meals in college, will be £9 10s. 0d. per delegate. Those who wish to have further information should write to the Oxford Conference Secretariat, The Institution of Engineering Inspection, 616 Grand Buildings, Trafalgar Square, London, W.C.2. This will involve no obligation but will ensure that full details will be sent as soon as they are available.

Dust Control Installation

Wishing to install modern dust collection equipment for two lines of grinding and polishing machines, the Aluminium Bronze Company Limited recently placed an order with **Dallow Lambert and Company Limited** for two Dallow Lambert size MG80 wet dedusters.

These two wet dedusters have 8,000 ft^3 of air per min. capacity and are self-contained with 30 h.p. motorized fans and drag link sludge ejectors. The sludge is discharged into two vertical hoppers located at the end of the building on which the dedusters are mounted and the quadrant gates at the base of the hoppers can be easily opened for disposal of the accumulated sludge.

To comply with requests from the Factory Inspectorate, weighted explosion relief doors are fitted to the outlet headers immediately prior to the fan inlets. The design of this type of wet collector ensures that the hoods serving the polishing machines and grinders are served by a constant air flow, and maintenance of an installation of this type is reduced to a minimum.

Lubrication Systems

From **Castrol Industrial Limited** comes news of their latest development in two-line centralized lubrication systems suitable for either oil or grease. Known as the Universal Centralised Lubrication System, it is based on a new positive dispensing unit.

Dispensing units, which can be made up into assemblies having from two to eight outlets, can be arranged for any desired combination of parallel and progressive operation. Advantage can thus be taken of the best features of both arrangements by connecting the units progressively for main lubrication points and in parallel for secondary points.

For large installations, power operated pumps would be proposed and for smaller installations, where continuous lubrication is not required, hand-operated pumps are provided. The amount of lubricant discharged from each unit can be adjusted as required. Also available are timers, starters, and control and warning equipment.

Foundry Exhibition

From June 20 to June 22 next, a Foundry Art and Craft Exhibition is to be held at the Birmingham University. This exhibition, which is sponsored by the **Association of Bronze and Brass Founders,** is designed to interest undergraduates, including those who have taken their exams. and are waiting for degree day, and presents an opportunity to make them realize the many uses of castings and their importance to industry. It is also hoped that the exhibition will be visited by many young people of school-leaving age.

James Booth's Modernization

A large plate-stretching machine has been ordered by James Booth Aluminium Limited from **Fielding and Platt Limited.** The machine, which will be in operation early next year, will cost approximately £150,000, including installation.

It will be used for flattening aluminium alloy plates, for use in shipbuilding, in the transport industry and various other engineering applications. The maximum length of plate which can be handled on the new 144 in. wide machine is 50 ft., and the maximum thickness is 1 in.

The ordering of this stretching machine is the latest step in the Booth current £5 million modernization and expansion programme, and it will be used in conjunction with the 148 in. four-high hot reversing mill which is now being installed at the company's works at Kitts Green, Birmingham.

Induction Furnace

As a result of a number of requests, **Edwards High Vacuum Limited** have recently introduced further developments in their medium size induction furnace, which is now available with a coil assembly of 100 lb. steel capacity which is fully interchangeable with the 56 lb. coil which has hitherto been the nominal capacity.

The melting capacity of the furnace may now be altered by the use of either a 28-, 56- or 100-lb. coil assembly, all of which are fully interchangeable. The standard furnace is fitted with a high capacity vapour booster pump designed specially for vacuum processes where large quantities of gas are evolved and low ultimate pressures are required in minimum time.

A Birmingham Event

At the Bingley Hall, Birmingham, from May 29 to June 3, the **Industrial Equipment and Services Exhibition** will be held. This event is supported by the British Institute of Management, the Birmingham Branch of the Purchasing Officers' Association, the Institute of

Industrial Supervisors and the Illuminating Engineering Society.

It is understood that most of the space available has been sold, and during the run of the exhibition a Careers Exhibition, organized by the civic authorities, will be held in a separate part of the hall.

Sharing Scientific Equipment

A scheme for sharing scientific equipment between industrial companies in South-East England has recently been announced by the F.B.I., London and South-Eastern Region. It is believed to be the first arrangement of its kind in England and Wales, if not in the United Kingdom.

A large proportion of the 126 industrial firms represented in the Region's research directors' discussion group have submitted two lists of items of equipment—one of items they are prepared to make available to other companies, the other of equipment to which they would like to have access. These lists are now being circulated to all members of the group with the suggestion that "offerers" and "seekers" should get in direct contact. It is hoped that other companies will be moved to participate as a result of this initial circularization. The idea arose from a suggestion made by a member of the group.

U.K. Tin Statistics

It is reported by the British Bureau of Non-Ferrous Metal Statistics that consumption of refined tin in the U.K. during February 1961 was 1,760 tons, compared with 1,803 tons in January, a decrease of 2 per cent. Consumption of refined tin in the first two months of this year amounted to 3,563 tons and was 194 tons less than in the corresponding period of 1960. Stocks of refined tin at the end of February were 12,076 tons, compared with 11,865 tons at the end of January.

Forthcoming Event

Early notice is given of the annual conference of the **Electron Microscopy Group** of the Institute of Physics and The Physical Society, which is to be held this year from July 10 to July 14 at the University of Nottingham.

At this conference the following main topics will be discussed:—(a) electron microscopes and electron optics; (b) electron microscopy of thin films; (c) the theory and scope of electron diffraction methods; and (d) miscellaneous techniques and applications of electron microscopy.

Limited accommodation will be available in a University Hall of Residence. Registration is necessary, and further information and application forms will be available from the Administration Assistant, The Institute of Physics and The Physical Society, 47 Belgrave Square, London, S.W.1.

Aluminium Rolling Stock

In connection with the exhibition of the uses of aluminium in railway rolling stock, organized by Centre International de Développement de l'Aluminium in Strasbourg in June last year, the **Aluminium Development Association** has now issued a brochure dealing with the exhibition. It is noted in the foreword to the book that Great Britain has probably a larger number of aluminium railway passenger vehicles, in service and in project, than any other country.

The main text opens with a brief account of C.I.D.A. itself, a note concerning the technical discussions, and then follows a large number of illustrations, many in colour, of the exhibits.

New Factory Opening

News from **Hills Precision Die Castings Ltd.** is that their new factory extension and office block at Hall Green, Birmingham, which have just been completed, will be officially opened on May 3 next by the Rt. Hon. Aubrey Jones, M.P.

Copper Development

On Wednesday evening of last week some 80 guests were entertained by the **Copper Development Association** at their headquarters in London. Amongst those present were council members and representatives of the Association's member companies, members of the British Non-Ferrous Metals Federation and its development committee, and of the copper and nickel industry committee of the British Non-Ferrous Metals Research Association, together with members of their staff.

Visitors from Denmark

A party of 26 members of the Danish Union of Electroplaters will be arriving at Harwich on Sunday, April 16, for a seven-day visit to this country. Arrangements for the tour have been made by **W. Canning and Company Ltd.**, and one of their directors will meet the visitors at Harwich.

Works visits have been arranged for two days of the tour, while to balance the industrial interest of the visit a tour of the Shakespeare country has been arranged, as well as other places of historic interest. Accompanying the party throughout will be Mr. Petersen, of F. L. Bie A/S of Copenhagen, the Danish agents for W. Canning and Co. Ltd.

Industrial and Factory Law

A course of lectures on Industrial and Factory Law will be given by Mr. Harry Samuels, O.B.E., M.A., under the auspices of the **Industrial Welfare Society,** at their headquarters, 48 Bryanston Square, London, W.1, on May 9-11.

The course covers the legal groundwork necessary to industrial managers and executives and, in view of recent important legislative changes in this sphere, is also intended as a refresher course. Further particulars may be obtained from the secretary of the society.

New Warehouse

It has been announced by **Aston Aluminium Warehouses Limited,** of Birmingham, that they have opened a new warehouse in Cardiff at Pengam Airport, Tremorfa, Cardiff, with the telephone number of Cardiff 36040. The warehouse will be under the management of Mr. S. D. Parker.

Metal Products Company

A new company is to be formed jointly by the **AEI Lamp and Lighting Company Ltd.** and **The General Electric Company Ltd.** for the manufacture and sale of molybdenum, tungsten and other metal products associated with the electric lamp and radio valve industries. The headquarters of the new company will be at North Wembley, Middx.

News from Scotland

It is reported that the **Scottish Stamping and Engineering Co. Ltd.,** of Ayr, a Guest, Keen and Nettlefolds Ltd. subsidiary, is to convert its steam system to compressed air, installing a major £250,000 scheme to effect the change. The move is dictated partly by a need to meet complaints regarding grit emission and partly to provide an efficient and competitive system for the plant, which is gearing up to meet the expansion of the motor car industry in Scotland.

Scottish Aviation Ltd., of Prestwick, originally concerned only with aircraft manufacture, began a policy of diversification two years ago and now reports steady progress in the light engineering and fabrication field. Further development along these lines is now planned.

Electrical Resistance Furnaces

A revised and enlarged series of data sheets, the 1740 series, on their range of platinum-wound electrical resistance furnaces and control units has been issued by **Johnson, Matthey and Company Ltd.**

Newly introduced is the ash fusion and controlled atmosphere furnace, type K45F. This is primarily intended for the determination of the fusion points of coal and coke ash by the method described in B.S.1016: Part 15.

Developed from the type K45B, the ash fusion furnace has an impervious alumina tube of $1\frac{7}{8}$ in. bore which projects from each end. Both ends of the alumina tube are fitted with gas sealing attachments, one with a heat-resisting glass window so that specimens can be observed, the other with a bursting disc to protect the operator in the event of an explosion in the tube. Reducing conditions can be maintained with a gas flow of less than 0·5 litres/min., and fusion determinations can be made at temperatures up to 1,400°C. By removing the alumina tube, the furnace can be used for heating in air up to 1,500°C. in a combustion chamber measuring $21\frac{1}{2}$ in. long by $2\frac{1}{2}$ in. internal diameter. The control unit recommended for the K45F furnace is type C8, which can be used with all other JMC furnaces except type TK2.

In addition to the K45F furnace, the full range of JMC furnaces includes eight general-purpose furnaces with cylindrical combustion chambers and three with rectangular combustion chambers, for maximum operating temperatures of 1,350°-1,500°C., and the TK2 thermocouple calibration furnace operating at up to 1,775°C. The largest rectangular combustion chamber available in the range measures 12 in × 6 in × 5 in. All furnaces are constructed with ample thermal insulation, so that they can be used on an unprotected bench top; all except the TK2 are supplied with platinum: rhodium-platinum thermocouples as standard.

New Swiss Aluminium Smelter

Aluminium-Industrie-Aktiengesellschaft of Chippis announced in its report for 1960 that it will start soon the construction of a new aluminium smelter at Steg. Simultaneously, work on the installation of a modern strip rolling mill and on the expansion of the pressings plant will begin at Chippis. The company's aluminium smelters at Chippis (Switzerland), Porto Marghera (Italy), Rheinfelden (West Germany) and Lend (Austria) increased their output in 1960, it was stated.

Aluminium Bridges

Two aluminium highway bridges scheduled for completion this summer at Amityville, Long Island, will be the first ever placed in service utilizing an aircraft-type, stressed-sheet design. Sale of the

structures to the State of New York marks the entry of **Kaiser Aluminum and Chemical Corporation** into a new market involving the manufacture and distribution of prefabricated aluminium components for bridge construction.

The Kaiser Aluminum Unistress Bridge, as it has been named, is technically described as a semi-monocoque structure composed of triangular shaped beams bolted together edge-to-edge to form a roadway base. Each beam is a "cell" fabricated in the shop from aluminium sheet and stiffened inside with aluminium extrusions for maximum strength per pound of metal used. Standard concrete paving, poured directly on the deck, works integrally with the aluminium components.

The aluminium sheet forming the roadway base has corrugations running the length of the bridge which not only enhance the strength of the structure but eliminate the need for concrete formwork. The two structures in Amityville will be identical, measuring 212 ft. in length and 86 ft. in width. Each bridge will comprise four spans made up of 76 ft. and 30 ft. beams. A total of 376,000 pounds of 6061-T6 alloy aluminium sheet, plate and extrusions are involved.

Molybdenum Disulphide

We are informed by **K. S. Paul (Molybdenum Disulphide) Ltd.** that it has now been found possible to increase still further the resistance of Moly-VI-Bond to abrasion, to oxidation, and to attack by acids and alkalis by the addition of some 2 per cent of a special composite-type resin which also improves the elasticity of the film, so facilitating subsequent processing of light alloys, tin plate, steel, etc.

The new "improver" is said to be colourless, non-toxic, and free from taste or smell. In use, the improver is simply mixed with Moly-VI-Bond when the mixture has a minimum shelf life of four months. Application of the bonded coating is unchanged except that hot curing is essential (for example, 1½ hr. at 180°C. or 3-5 min. at 340°C.). Sample packages of ready mixed Moly-VI-Bond with improver are available for experimental purposes at a price of 7s. 6d.

Market Managers

It has been announced by **Honeywell Controls Ltd.** that Mr. W. R. Owen has been given responsibility for the Cardiff and Manchester branches of the firm, in addition to continuing as Birmingham branch manager. This follows the transfer of Mr. T. Jackson and Mr. R. Robson from Manchester and Cardiff respectively to head office positions at Greenford.

Mr. Jackson will now be field sales manager for heating, ventilating and air conditioning controls in commercial buildings. Mr. Robson will be market sales manager for the metal processing industries. There are two other new market sales managers: Mr. E. R. Amery for the chemical industry and Mr. H. Wigman for the food and fibre industries.

Equipment for Rolling Mills

An agreement has been concluded between **Bruce Peebles and Co. Limited,** of Edinburgh, and REGA Brucker and Co., of Siegburg, Germany, for the joint production and marketing of complete electrical equipments for the operation and control of ferrous and non-ferrous hot and cold rolling mills. This agreement unites in this field the resources of these two well-known organizations, each of which has had extensive experience in the design and manufacture of electrical equipment incorporating the most advanced techniques in the specialized rolling field.

Under the arrangements made in the agreement, which covers the supply of equipment in the whole of the United Kingdom and in Eire, rotating machines and rectifiers will be built by Bruce Peebles, and the electronic controls, programming, optimization, and automatic gauge control equipment will be designed by REGA Brucker and manufactured either by them, or, under licence, by Bruce Peebles. Among the activities already in progress are contracts entailing full responsibility for the complete electrical equipment for several rolling mills.

Laboratory Equipment

Britain spent nearly £500,000,000 on research in 1958-59—even more in 1959-60, for which returns are not yet complete—and is expected to spend considerably more in the current year. To hold a world lead in technology demands continual development of an inconceivable variety of new equipment and techniques.

The latest developments in nearly all fields of advanced technology will be shown at the **Laboratory Apparatus and Materials Exhibition,** from June 19-22 at the Royal Horticultural Society's New Hall, Westminster. Seventy of the leading British and overseas firms manufacturing laboratory instruments and materials will be exhibiting, and twelve lecturers of international repute will speak in the R.H.S. Lecture Hall during the exhibition. Lectures include: "Recent Advances in Techniques at the Tin Research Laboratory"; "High Voltage Paper Electro-Phoresis"; "Automation in the Medical Laboratory"; and "Modern Methods for the Microbiological Examination of Foods".

Rapid Tinning of Aluminium

Under this heading in our issue last week (page 268) we referred to a low-temperature fluxless solder, Tin-A-Lum, which enables tinning of most metals to be readily carried out. We understand that this solder is manufactured and supplied in the U.K. by **Industrial Synthetics (Overseas) Ltd.,** Tin-A-Lum Division.

Representation

Until the appointment of a successor to the late Mr. A. E. A. McGrath, we are informed by **Fescol Limited** that the services of their technical representatives will be at the disposal of their customers in the Midlands and South Wales if they will contact the company's Brownhills works or the London office.

Good Publicity

A well produced and useful little folder has just been distributed by **Incandescent Heat Company Ltd.,** showing how their works at Smethwick may be reached by road, bus and rail.

Radiation Protection

A new catalogue of radiation protection materials, equipment and accessories, of interest to industrial safety officers, radiographers and all concerned with gamma or X-rays, is now available from Research and Control Instruments Ltd. Materials are listed suitable for every type of laboratory, production, or site work, and the advisory service offered by the firm is described.

Obituary

Mr. A. E. A. McGrath

It is with much regret that we have to record the death of Mr. A. E. A. McGrath, senior technical representative of Fescol Limited, who passed away suddenly on Saturday last. Mr. McGrath joined the company in February, 1934, and has represented it successively in London, the North of England, Scotland and, since the war, in the Midlands and South Wales.

Forthcoming Meetings

April 17—Institute of Metal Finishing. London Branch. Northampton College of Technology, St. John Street, London, E.C.1. "Plating of Zinc-Based Die-Castings." J. Edwards. 6.15 p.m.

April 18 — Institute of Metal Finishing. Midland Branch. James Watt Memorial Institute, Great Charles Street, Birmingham. "How Much Polishing Is Needed?" M. A. Price. 6.30 p.m.

April 18 — Institute of Metal Finishing. South-West Branch. Royal Hotel, Bristol. Annual General Meeting and Film Show. 7.30 p.m.

April 20—Liverpool Metallurgical Society. Department of Metallurgy, University of Liverpool. "Continuous Casting of Aluminium Alloys." Dr. W. M. Doyle. 7 p.m.

April 21—West of England Metallurgical Society. College of Technology, Ashley Down, Bristol. "Temperature Measurement." J. A. Hall. 7.30 p.m.

Metal Market News

THE British Bureau of Non-Ferrous Metal Statistics has issued details for February, which, when allowance is made for the shorter month, do not make at all a bad showing. Consumption during February of copper, refined and scrap, amounted to 55,946 tons, compared with 59,155 tons in January. Stocks declined, the total at February 28 being 114,919 tons, compared with 122,694 tons at the end of the previous month. In lead, consumption was 30,430 tons against 31,145 tons, and stocks declined from 68,856 tons to 62,928 tons. Zinc followed a similar trend, consumption, at 28,118 tons, being about 600 tons lower than in January, while stocks on hand at February 28 stood at 59,958 tons, compared with 63,152 tons available at the end of January. Markets were fully steady last week, and the New York futures dealing in copper operated at a higher level than in the previous week. On this side, business with consumers was not very brisk, but some Continental enquiry was reported. The London Stock Exchange put on a good show, but Wall Street looked a little uncertain. However, sentiment in the States seems to be improving, and there are hopes that before long a definite improvement in the state of industry will be discernible. Some observers, however, feel that it will be a few months yet before the tide turns.

The outstanding feature of last week's trading on the Metal Exchange was the strong and sustained advance in the price of tin, which closed above £836 for three months, while cash was traded during the midday session at that level. Continental buying was reported after the Easter holidays, and this was reflected in Whittington Avenue, where the turnover for the week amounted to about 1,400 tons. Final values were £829 10s. 0d. cash, which showed a gain of £4 10s. 0d., and £833 three months, which closed £5 higher on the week. Actually, at midday on Friday, the official prices were £2 higher than in the afternoon. It was generally assumed that the Pool was a seller of cash tin on Friday's midday market, for the quotation then stood within the permissive range at which the Tin Pool manager may sell tin. Other news about tin is that February consumption added up to 1,760 tons, against 1,803 tons in January, while stocks at the end of February stood at 12,076 tons.

The standard copper market also showed strength, especially during the second half of the week, for buying by Japan was reported, and Comex influenced London upwards. In all, the turnover amounted to 10,100 tons for the four days, and cash closed £4 higher at £228 15s. 0d., while three months improved by £3 15s. 0d. to £229 10s. 0d. It will be noted that the contango narrowed from £2 to only 15s., but this was thought to be temporary. Consumers in the U.K. also showed some interest. Warehouse stocks improved by 122 tons to 14,972 tons. In the other metals, stocks of lead rose from 10,881 tons to 11,307 tons, while there was a gain of 436 tons in zinc stocks to 4,226 tons. In that metal, there was a turnover of 4,200 tons, cash improving by 2s. 6d. to £83 17s. 6d., while three months was also 2s. 6d. higher at £83 12s. 6d. Some 5,700 tons of lead changed hands, with cash 25s. up at £67, and three months 22s. 6d. better at £68.

Birmingham

The trade situation in the Midlands has made steady progress since the beginning of the year. The unemployment figures have been declining, and the amount of short time, particularly in the motor trade, has been cut. Only this week, redundancy notices at a big car works, affecting a large number of men, have been withdrawn as the result of additions to the order book. The recession has, in fact, lasted a much shorter time than was predicted in the autumn of last year. The metal trades are benefiting considerably from the sustained activity in the building industry. New orders are coming forward which will ensure employment on both home and export account.

For most descriptions of steel, the time required for delivery has been shortened by comparison with the conditions which obtained during the peak last year. But there are still delays for structural material, and for other steels used in the building and civil engineering industries. Makers of rods and reinforcing bars are exceptionally busy. Demand for steel sheets for motor cars and commercial vehicles is strong. Foundries are getting good orders for castings from the light engineering industries, and the motor trade. A shortage of semi-finished steel is unlikely as good stocks are held in re-rollers' works.

New York

Copper futures, after early steadiness firmed at the week-end on new speculative buying. Dealings were moderate. Traders said physical copper continued brisk. Active Japanese demand was noted in the export market. Producers and custom smelters reported active sales. Leading copper sources said that if demand continues as brisk for the next fortnight, as it is currently, custom smelters may raise their price above 29 cents, since the firmness in scrap copper is putting a price squeeze on them.

Tin was firm but quiet. Lead was moderately active. Zinc was active, mostly in prime western zinc. In late dealings, the tin price held at earlier levels, but consumers showed negligible interest. Scrap copper was firmer, up ¼ cent per lb. to 24 cents. Export copper continued firm.

Eleven lead-zinc producing nations will meet in New York next month to explore the possibility of an International Commodity Agreement to stabilize markets of the metals, according to the Journal of Commerce. The nations will also discuss other "price stabilization mechanisms" such as buffer stocks, and more formal and mandatory country-by-country production cutbacks than the voluntary system used hitherto.

France

News from Paris is to the effect that the scrap market was quiet during the week to April 6. Trading failed to revive after the Easter holidays, and cautious dealings were noted. Copper was settled in reduced activity, but brass and bronze rose in price on some demand. The downward trend of aluminium prices continued, reflecting the lack of export demand. Prices were reported to be still too high to attract any foreign interest. Buyers of lead and zinc were reserved.

Bolivia

The completion of a $40,000,000 so-called triangular loan, for the development of Bolivia's nationalized mining industry, was announced officially last week by the Bolivian Government. The credits were granted in equal parts by the United States Government, the Inter-American Development Bank, and West Germany (through the firm of Saltzgitter Machinen Aktiengesellschaft) the announcement said.

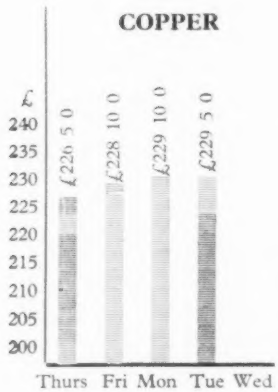
A five-year plan for the development of the mines would commence on May 1 next with an initial investment of $11,000,000. A meeting would be held in Washington on May 17 to conclude details of the loans. The President of the Bolivian Mining Corporation stated that a credit equivalent of $2,000,000 had also been negotiated in London against future tin shipments. He declared that the Corporation was at present operating at a loss of $700,000 a month.

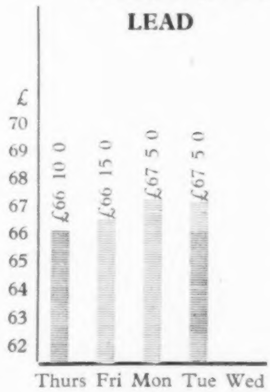
The Inter-American Development Bank had also granted a $10,000,000 credit to the Corporation for the development of other sources of supply and the industrialization of the country. The departure of a Bolivian commission to Russia to study a proposed Soviet loan for the installation of tin smelting equipment in Bolivia has not yet been announced.

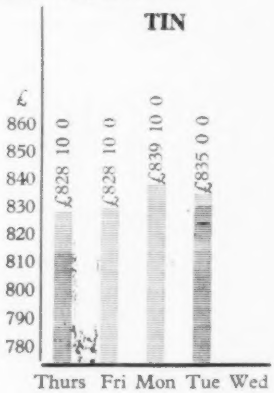
Non-Ferrous Metal Prices

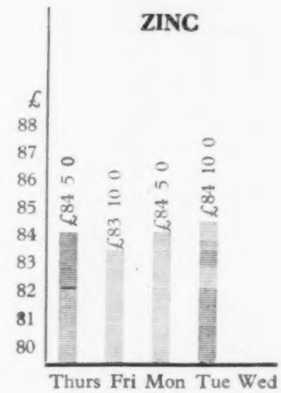
London Metal Exchange

Thursday 6 April to Tuesday 11 April 1961









Primary Metals

All prices quoted are those available at 2 p.m. 11/4/61

		£	s.	d.
Aluminium Ingots	ton	186	0	0
Antimony 99·6%	,,	237	10	0
Antimony Metal 99%	,,	230	0	0
Antimony Oxide				
Commercial	,,	194	10	0
Antimony White				
Oxide	,,	212	0	0
Arsenic	,,	400	0	0
Bismuth 99·95%	lb.		16	0
Cadmium 99·9%	,,		11	0
Calcium	,,	2	0	0
Cerium 99%	,,	15	0	0
Chromium	,,		6	11
Cobalt	,,		12	0
Columbite	per unit	8	10	0
Copper H.C. Electro.	ton	229	5	0
Fire Refined 99·70%	,,	228	0	0
Fire Refined 99·50%	,,	227	0	0

		£	s.	d.
Copper Sulphate	ton	77	0	0
Germanium	grm.	—		
Gold	oz.	12	10	7½
Indium	,,		10	0
Iridium	,,	24	0	0
Lanthanum	grm.		15	0
Lead English	ton	67	5	0
Magnesium Ingots	lb.			
99·8%	,,		2	2½
99·9+%	,,		2	3
Notched Bar	,,		2	9½
Powder Grade 4	,,		5	6
Alloy Ingot, AZ91X		1	11¾-2	1¼
Manganese Metal	ton	280	0	0
Mercury	flask	68	0	0
Molybdenum	lb.	1	10	0
Nickel	ton	600	0	0
F. Shot	lb.		5	5
F. Ingot	,,		5	6
Osmium	oz.	20	0	0
Osmiridium	,,		—	

		£	s.	d.
Palladium	oz.	9	0	0
Platinum	,,	30	5	0
Rhodium	,,	46	0	0
Ruthenium	,,	16	0	0
Selenium	lb.	2	6	6
Silicon 98%	ton	122	0	0
Silver Spot Bars	oz.		6	7[illegible]
Tellurium Sticks	lb.	2	0	0
Tin	ton	835	0	0
***Zinc**				
Electrolytic	ton		—	
Min 99·99%	,,		—	
Virgin Min 98%	,,	84	6	3
Dust 95/97%	,,	125	0	0
Dust 98/99%	,,	131	0	0
Granulated 99+%	,,	109	6	3
Granulated 99·99+%	,,	124	8	9

**Duty and Carriage to customers' works for buyers' account.*

Foreign Quotations

Latest available quotations for non-ferrous metals with approximate sterling equivalents based on current exchange rates

	Belgium fr/kg≏£/ton		Canada c/lb≏£/ton		France fr/kg≏£/ton		Italy lire/kg≏£/ton		Switzerland fr/kg≏£/ton		United States c/lb≏£/ton	
Aluminium			26.00	210 12	2.43	179 11	370	216 1	2.50	210 5	26.00	207 4
Antimony 99.0					2.30	170 0	500	292 0			29.00	231 2
Cadmium					15.75	1,069 0					150.00	1,195 10
Copper												
Crude												
Wire bars 99.9							430	251 2				
Electrolytic	31.00	226 11	27.50	222 15	3.15	232 15			2.75	231 5	29.00	231 6
Lead			10.00	81 0	.96	70 18	164	96 15	.78	65 11	11.00	87 13
Magnesium												
Nickel			70.00	567 0	9.00	665 2	1,180	689 2	7.50	630 15	74.00	589 15
Tin	113.75	831 7			11.61	843 3	1,530	893 10	9.65	811 11	103.87	827 16
Zinc												
Prime western			12.25	100 4 0								
High grade 99.95			12.85	104 17 0								
High grade 99.99			13.25	107 6 0					1.10	92 10		
Thermic					1.20	88 13						
Electrolytic					1.28	94 13	191	111 10			13.00	104 0

Non-Ferrous Metal Prices (continued)

Ingot Metals

All prices quoted are those available at 2 p.m. 11/4/61

Aluminium Alloy (Virgin)		£	s.	d.
B.S. 1490 L.M.5	ton	210	0	0
B.S. 1490 L.M.6	„	202	0	0
B.S. 1490 L.M.7	„	216	0	0
B.S. 1490 L.M.8	„	203	0	0
B.S. 1490 L.M.9	„	203	0	0
B.S. 1490 L.M.10....	„	221	0	0
B.S. 1490 L.M.11....	„	215	0	0
B.S. 1490 L.M.12....	„	223	0	0
B.S. 1490 L.M.13....	„	216	0	0
B.S. 1490 L.M.14....	„	224	0	0
B.S. 1490 L.M.15....	„	210	0	0
B.S. 1490 L.M.16....	„	206	0	0
B.S. 1490 L.M.18....	„	203	0	0
B.S. 1490 L.M.22....	„	210	0	0

Aluminium Alloys (Secondary)				
B.S. 1490 L.M.1	ton	171	0	0
B.S. 1490 L.M.2	„	174	0	0
B.S. 1490 L.M.4	„	180	0	0
B.S. 1490 L.M.6	„	181	0	0

*Aluminium Bronze				
BSS 1400 AB.1......	ton			
BSS 1400 AB.2......	„			

*Brass		£	s.	d.
BSS 1400-B3 65/35 ..	ton			
BSS 249	„	—		
BSS 1400-B6 85/15 ..	„			

*Gunmetal				
R.C.H. 3/4% ton	„	—		
(85/5/5/5) LG2	„			
(86/7/5/2) LG3	„			
(88/10/2/1)	„			
(88/10/2/½)	„			

*Manganese Bronze				
BSS 1400 HTB1.....	„			
BSS 1400 HTB2.....	„			
BSS 1400 HTB3.....	„			

Nickel Silver				
Casting Quality 12%	„	240	0	0
„ „ 16%	„	255	0	0
„ „ 18%	„	295	0	0

*Phosphor Bronze				
B.S.1400P.B.1.(A.I.D. released)	„			
B.S. 1400 L.P.B.1	„			

Average prices for the last week-end.

Phosphor Copper		£	s.	d.
10%	ton	256	0	0
15%	„	258	0	0

Phosphor Tin				
5%	„	900	0	0

Silicon Bronze				
BSS 1400-SB1	„	284	0	0

Solder, soft, BSS 219				
Grade C Tinmans ...	„	383	10	0
Grade D Plumbers ..	„	306	10	0
Grade M	„	421	15	0

Solder, Brazing, BSS 1845				
Type 8 (Granulated)	lb.	—		
Type 9 „	„	—		

Zinc Alloys				
BSS 1004 Alloy A ..	ton	117	18	9
BSS 1004 Alloy B....	„	121	18	9
Sodium-Zinc	lb.		2	7

Semi-Fabricated Products

Prices vary according to dimensions and quantities. The following are the basis prices for certain specific products.

Aluminium		£	s.	d.
Sheet 10 S.W.G.	lb.		2	10½
Sheet 18 S.W.G.	„		3	0½
Sheet 24 S.W.G.	„		3	3½
Strip 10 S.W.G.	„		2	10½
Strip 18 S.W.G.	„		2	11½
Strip 24 S.W.G.	„		3	1
Circles 22 S.W.G.	„		3	4½
Circles 18 S.W.G.	„		3	3½
Circles 12 S.W.G.	„		3	2½
Plate as rolled	„		2	10
Sections	„		3	4
Wire 10 S.W.G.	„		3	1½
Tubes 1 in o.d. 16 S.W.G.	„		4	4

Aluminium Alloys		£	s.	d.
BS1470. HS19W.				
Sheet 10 S.W.G.	„		3	3
Sheet 18 S.W.G.	„		3	5½
Sheet 24 S.W.G.	„		4	1
Strip 10 S.W.G.	„		3	3
Strip 18 S.W.G.	„		3	4½
Strip 24 S.W.G.	„		4	0½
BS1477. HP30M.				
Plate as rolled	„		3	1
BS1470. HC15WP.				
Sheet 10 S.W.G.	„		4	3
Sheet 18 S.W.G.	„		4	8½
Sheet 24 S.W.G.	„		5	8½
Strip 10 S.W.G.	„		4	4
Strip 18 S.W.G.	„		4	8½
Strip 24 S.W.G.	„		5	4½
BS1477. HPC15WP.				
Plate heat treated ...	„		3	10½
BS1475. HG19W.				
Wire 10 S.W.G.	„		4	2
BS1471. HT19WP.				
Tubes 1 in. o.d. 16 S.W.G.	„		5	5
BS1476. HE19WP.				
Sections	„		3	4
Split tube				
19 S.W.G. (⅛")	„		4	2
20 S.W.G. (⅜")	„		3	11
21 S.W.G. (⅜")	„		4	1
22 S.W.G. (¼")	„		4	11
Welded tube				
14 to 20 S.W.G. (sizes ¼" to 1⅛")	„	3/10½ to 5/8½		

Brass		£	s.	d.
Tubes	lb.		1	10
Brazed Tubes	„		3	3
Drawn Strip Sections	„		3	2¾
Sheet	ton	200	0	0
Strip	„	200	0	0
Extruded Bar	lb.		2	0½
Condenser Plate (Yellow Metal)............	ton	188	0	0
Condenser Plate (Naval Brass)	„	200	0	0
Wire	lb.		2	8½

Beryllium Copper		£	s.	d.
Strip	„	1	4	11
Rod	„	1	1	6
Wire	„	1	4	9

Copper		£	s.	d.
Tubes	lb.		2	2½
Sheet	ton	263	0	0
Strip	„	263	0	0
H.C. Wire	„	280	5	0

Cupro Nickel		£	s.	d.
Tubes 70/30	lb.		3	6¼

Lead		£	s.	d.
Pipes (London)	ton	107	0	0
Sheet (London)	„	104	15	0
Tellurium Lead	„	£6 extra		

Nickel Silver		£	s.	d.
Sheet and Strip 10%..	lb.		3	10½
Wire 10%	„		4	3½

Phosphor Bronze		£	s.	d.
Wire	„		4	1½

Titanium (1,000 lb. lots)			
Billet 4½" to 18" dia.....	lb.	47/-	48/-
Rod ¼" to 4" dia........	„	85/-	53/-
Wire ·036"-232" dia....	„	159/-	99/-
Strip ·001" to ·048"....	„	350/-	68/-
Sheet 8'×2'. 20 gauge	„	73/-	
Tube, representative average gauge	„	198/-	
Extrusions	„	90/-	

Zinc		£	s.	d.
Sheet	ton	122	5	0
Strip	„	nom.		

Domestic and Foreign

Merchants' average buying prices delivered, per ton, 11/4/61.

Aluminium	£
New Cuttings	141
Old Rolled	114
Segregated Turnings	79

Brass	£
Cuttings	162
Rod Ends	145
Heavy Yellow	138
Light	132
Rolled	151
Collected Scrap	137
Turnings	139

Copper	£
Wire	208
Firebox, cut up	205
Heavy	203
Light	200
Cuttings	210
Turnings	184
Braziery	180

Gunmetal	£
Gear Wheels	204
Admiralty....................	204
Commercial	189
Turnings	184

Lead	£
Scrap	56

Nickel	£
Cuttings	—
Anodes	555

Phosphor Bronze	£
Scrap	189
Turnings	184

Zinc	£
Remelted	76
Cuttings	66
Old Zinc	46

Financial News

Alcan Malayan Co.

From Montreal, Aluminium Limited have announced the formation of a company in the Federation of Malaya to be known as Alcan Malayan Aluminium Company Limited. The new company will build an aluminium rolling mill, the first in Malaya, to produce aluminium sheet, circles and building sheet. Initially, the Malayan subsidiary will be wholly-owned by Aluminium Limited, who will finance the enterprise and furnish technology. Malay personnel will operate the plant and steps will be taken to train Malayan managerial staff. Located at Petaling Jaya, near Kuala Lumpur, construction is expected to start immediately. Estimated cost of the enterprise is over $1,300,000.

Thos. Bolton and Sons

Net profit 1960 £195,388 (£92,993) and distribution 12½ per cent (10 per cent). Fixed assets £1,564,420 (£1,347,864), current assets £3,538,010 (£3,081,207) and liabilities £1,672,578 (£1,190,732). Commitments £195,000 (£202,000).

A. Reyrolle and Co.

Accounts for the year show a net profit of £1,560,306, compared with £1,428,021 for the previous year. A final dividend is recommended of 6½ per cent, making 9½ per cent for the year as against 8½ per cent for 1959.

New Companies

The particulars of companies recently registered are quoted from the daily register compiled by Jordan and Sons Limited, Company Registration Agents, Chancery Lane, W.C.2.

Cornish Smithy Limited (685631), Trelawne Cross, Trelawne, Looe, Cornwall. Registered March 8, 1961. To carry on business of manufacturers of and dealers in brassware, brass fittings and utensils, etc. Nominal capital, £1,000 in £1 shares. Permanent directors: James Beddoes and Eileen Beddoes.

D. and E. Creed (Metal Fabrication) Limited (685837), 162 Uxbridge Road, W.13. Registered March 9, 1961. To take over the business of sheet metal workers carried on as "D. Creed and Co." at New Road, Harlington, Middx., etc. Nominal capital, £100 in £1 shares. Directors: Dennis Creed and Eileen E. Creed.

C. McKenna and Sons Limited (686791), Weatherley Street, Newcastle upon Tyne. Registered March 17, 1961. To take over business of scrap metal merchants carried on at Newcastle upon Tyne and Gateshead by Catherine, J., and P. Todd, etc. Nominal capital, £10,000 in £1 shares. Permanent directors: Mrs. Catherine Todd, John Todd, Peter Todd and Mrs. Mary Norwell.

Hill Bros. Metals Limited (686830), Park Street, Scunthorpe, Lincs. Registered March 17, 1961. Nominal capital, £10,000 in £1 shares. Directors: Arthur J. Hill, John E. Hill and Peter J. Hill.

Heat Extraction Limited (686953), 33 Blossom Street, Manchester, 4. Registered March 20, 1961. Nominal capital, £500 in £1 shares. Directors: Wm. A. Hall, Wm. J. P. Hall and Kenneth Blakemoor.

Mossfield Fabrications Ltd. (687084), 81 Lichfield Road, Shelfield, near Walsall. Registered March 21, 1961. To take over business of metal fabricating, welding, machining, etc., carried on as "B. Woolley and Son" at Shelfield, Walsall, etc. Nominal capital, £500 in £1 shares. Directors: Benjamin Woolley, Ellen Woolley and Anthony J. Woolley.

Thermal Exchanges Limited (687109), 15 Lower Belgrave Street, S.W.1. Registered March 21, 1961. To carry on the business of designers and constructors of heat exchange and process equipment, engineers, etc. Nominal capital, £1,000 in £1 shares. Directors to be appointed by subscribers.

France and Kendrick Limited (687492), Alexandra Road, Tipton, Staffs. Registered March 23, 1961. To carry on business of metal merchants and stockholders, etc. Nominal capital, £500 in £1 shares. Directors: Ronald France and Harold W. Kendrick.

Scrap Metal Prices

The figures in brackets give the English equivalents in £1 per ton:—

France (new francs per kilo):

Electrolytic copper scrap	(£218.0.0)	2.95
Heavy copper	(£218.0.0)	2.95
No. 1 copper wire	(£203.4.0)	2.75
Brass rod ends	(£164.1.0)	2.22
Zinc castings	(£67.19.0)	0.92
Lead	(£65.0.0)	0.88
Aluminium	(£134.9.0)	1.82

Italy (lire per kilo):

Aluminium soft sheet clippings (new)	(£178.2.0)	305
Lead, soft, first quality	(£80.0.0)	137
Lead, battery plates	(£44.19.0)	77
Copper, first grade	(£214.2.0)	365
Bronze, commercial gunmetal	(£178.2.0)	305
Brass, heavy	(£148.18.0)	255
Brass, light	(£134.6.0)	230
Brass, bar turnings	(£148.18.0)	255
Old zinc	(£64.4.0)	110

Japan (Yen per metric ton):

Electrolytic copper	(£—)	283,000
Copper wire No. 1	(£—)	265,000
Copper wire No. 2	(£—)	250,000
Heavy copper	(£—)	250,000
Light copper	(£—)	215,000
Brass, new cuttings	(£—)	200,000
Red brass scrap	(£—)	212,000

West Germany (D-marks per 100 kilos):

Used copper wire	(£204.19.0)	225
Heavy copper	(£204.19.0)	225
Light copper	(£182.4.0)	200
Heavy brass	(£132.1.0)	145
Light brass	(£95.13.0)	105
Soft lead scrap	(£52.16.0)	58
Zinc scrap	(£52.16.0)	58
Used aluminium unsorted	(£81.19.0)	90

Trade Publications

Impalco Aluminium. — Imperial Aluminium Company Limited, P.O. Box 216, Witton, Birmingham, 6.

A brochure of some 70 pages is devoted to technical data relating to this metal and its alloys. It is divided into four parts dealing with the three grades of the company's commercially pure aluminium; non-heat-treatable alloys; heat-treatable alloys, and brazing materials and other products. A number of tables are included such as weight, composition limits, mechanical properties, and comparison with other metals.

Induction Hardening. — Delapena and Son Limited, Tewkesbury Road, Cheltenham, Glos.

The latest publication of this company describes their Cold-Heat submerged induction hardening process. In addition to general details of the process, a good deal of technical data and photographs are included in this twelve-page brochure.

Counting Instruments. — Trumeter and Company Limited, Milltown Street, Radcliffe, Lancs.

A new and comprehensive catalogue of 20 pages features this company's range of counting and linear measuring machines, and includes many illustrations.

Melting Furnaces. — G.W.B. Furnaces Limited, P.O. Box 4, Dibdale Works, Dudley, Worcs.

This loose leaf catalogue, covering 44 pages, describes the GWB Lectromelt furnaces. In addition to considerable statistical data, a number of diagrams and illustrations are included.

Scientific Instruments. — George Kent Limited, Luton, Bedfordshire.

Specification sheets have been issued relating to this company's "Commander" air-operated receiving instruments and their float-operated open-channel flow-measuring instruments.

Tioxide Pigments. — British Titan Products Company Limited, 10 Stratton Street, London, W.1.

Three useful brochures have been produced dealing, respectively, with the performance of Tioxide pigments in a sand grinder, in a ball mill, and in high speed impeller mills. Technical details, charts and illustrations are given in each case.

Crucibles, Furnaces, etc. — Morganite Crucible Limited, Norton Works, Woodbury Lane, Norton, Worcs.

This coloured folder is devoted to details and illustrations of the range of "Suprex" crucible and furnaces provided by the company, and also of refractories for non-ferrous foundries and other foundry accessories.

Refractories.—Morgan Refractories Ltd., Neston-Wirral, Cheshire.

In this folder, a description of M.R. "Trumul", a Morgan refractory for industrial purposes, is given together with charts, technical data and illustrations.

The Plycast Process. — W. J. Hooker Limited, 239A Finchley Road, London, N.W.3.

The Plycast investment casting process is a product of Nicolas Herzmark, and W. J. Hooker Ltd. represent the process in this country. A 16-page brochure describes and illustrates this process with diagrams, photographs and technical details.

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£	£				Per cent	Per cent					
4,435,792	1	Amalgamated Metal Corporation ...	32/6	+3d.	11	9	6 15 6	32/6	26/3	35/-	26/6
400,000	2/-	Anti-Attrition Metal	1/-		NIL	4	NIL	1/-	0/9	1/6	0/9
43,133,593	Stk. (£1)	Associated Electrical Industries ...	44/9	—3d.	15	15	6 14 0	54/10½	40/3	67/3	38/3
3,895,963	1	Birfield	64/-	+7/3	10	15‡	3 2 6	64/-	45/-	51/3	29/-
4,795,000	1	Birmid Industries	96/-	+8/3	20	20D	4 3 3	96/6	71/3	74/9	56/-
8,445,516	Stk. (10/-)	Birmingham Small Arms	36/6		17½QT	12½	3 4 0	36/10½	24/9	30/6	18/3
203,150	Stk. (£1)	Ditto Cum. A. Pref. 5%	14/6		5	5	6 18 0	14/4½	14/-	17/4½	14/9
476,420	Stk. (£1)	Ditto Cum. B. Pref. 6%	16/6		6	6	7 5 6	17/6	16/9	20/-	17/1½
500,000	1	Bolton (Thos.) & Sons	48/9		12½	10	4 6 6	48/9	37/6	43/-	36/-
300,000	1	Ditto Pref. 5%	14/-		5	5	7 2 9	14/6	13/9	16/-	14/3
1,500,000	Stk. (£1)	British Aluminium Co. Pref. 6% ...	17/-		6	6	7 1 3	18/-	16/6	21/1½	17/7½
18,846,647	Stk. (£1)	British Insulated Callender's Cables	58/6	+1/3	13½	13½	4 12 3	58/6	50/4½	61/4½	47/-
20,456,599	5/-	British Oxygen Co. Ltd., Ord. ...	35/3	+1/9	16	16	2 5 6	35/3	26/3	35/-	19/10½
1,200,000	Stk. (5/-)	Canning (W.) & Co.	19/9	—1/-	15 + 8⅛C	25 + *2¼C‡	3 16 0	20/-	13/7½	19/9	13/7½
60,484	1/-	Carr (Chas.)	1/6		NIL	12½	—	1/6	1/-	2/3	1/-
555,000	1	Clifford (Chas.) Ltd.	28/-xd		12	10	8 11 6	29/-	26/-	35/-	28/9
45,000	1	Ditto Cum. Pref. 6%	15/3		6	6	7 17 6	15/3	15/1½	16/-	15/10½
300,000	2/-	Coley Metals	3/6	—3d.	15	15	8 11 6	4/2¼	3/6	5/-	3/4½
10,185,696	1	Cons. Zinc Corp.†	71/3		20	15	5 12 3	75/-	64/-	80/9	59/6
5,399,056	1	Davy-Ashmore	176/-		30‡	20	1 14 3	177/6	129/6	147/3	99/6
8,000,000	5/-	Delta Metal	23/9xd	—3d.	20	17½	4 4 3	25/4½	19/9	28/3	18/6
5,296,550	Stk. (£1)	Enfield Rolling Mills Ltd.	48/6xd	—1/-	15	15	6 3 9	52/3	45/-	56/9	45/-
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937,500	5/-	Glacier Metal Co. Ltd.	17/9	+3d.	13	11½	3 12 3	18/3	13/9	16/1½	11/1½
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696,780	10/-	Greenwood & Batley	25/6xcap		30W	30	5 17 9	27/-	23/9Z	33/6	29/1½
792,000	5/-	Harrison (B'ham) Ord.	12/-xd	—3d.	*20‡	*17½	4 3 3	13/6¾	12/-	15/10½	11/9
150,000	1	Ditto Cum. Pref. 7%	20/-		7	7	7 0 0	20/3	20/-	23/6	22/-
1,612,750	5/-	Heenan Group	15/4½		13	15	4 4 6	15/6	10/6	13/-	9/10½
251,689,407	Stk. (£1)	Imperial Chemical Industries ...	73/9xd	+2/9	13¾	11¼	3 14 9	73/9	63/1½	76/6	54/-
34,736,773	Stk. (£1)	Ditto Cum. Pref. 5%	15/-		5	5	6 13 3	15/9	14/10½	18/-	15/4½
29,196,118	**	International Nickel	125	+1½	$1.60	$1.50	2 6 0	126	104	105	84¾
300,000	1	Johnson, Matthey & Co. Cum. Pref. 5%	14/6		5	5	6 18 0	14/10½	14/-	16/6	14/6
6,000,000	1	Ditto Ord.	63/3	+1/6	12	12D	3 16 0	63/3	59/6	67/6	44/9
600,000	10/-	Keith, Blackman	21/-		17½	17½E	8 6 9	21/6	18/3	32/6	17/6
320,000	4/-	London Aluminium	12/4½	+1/3	12	10	3 17 6	12/4½	8/6	12/6	7/10½
765,012	1	McKechnie Bros. Ord	59/-	+1/-	17½F	15F	5 18 9	59/-	53/6	71/6	57/3
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50,628	6/-	Ditto (7½% N.C Pref.)	5/6		7½	7½	8 3 9	6/-	5/4½	6/6	5/9
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160,000	1	Mint (The) Birmingham	38/6		12½	10	6 9 9	38/6	36/-	39/-	33/6
80,000	5	Ditto Pref. 6%	76/3		6	6	7 17 6	77/6	76/-	80/-	75/-
5,187,938	Stk. (£1)	Morgan Crucible A.	64/-	+1/6	13	12	4 1 3	64/-	53/4½	63/-	47/6
1,000,000	Stk. (£1)	Ditto 5½% Cum. 1st Pref. ...	15/6		5½	5½	7 2 0	17/-	15/3	18/9	15/9
3,850,000	Stk. (£1)	Murex	47/-	+1/-	22½J	15	5 7 3	47/3	39/9	45/-	35/3
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750,000	Stk. (£1)	Ditto Pref. 5%	13/-		5	5	7 13 9	13/6	12/7½	17/6	13/3
6,863,807	Stk (£1)	Ditto Pref. 5% tax free	20/6	+6d.	*5	*5	7 5 0A	20/7½	19/9	24/6	20/1½
4,594,418	1	Ward (Thos. W.) Ord.	76/-	—1/3	13¾	25	3 15 0	78/-	64/6	94/-	63/-
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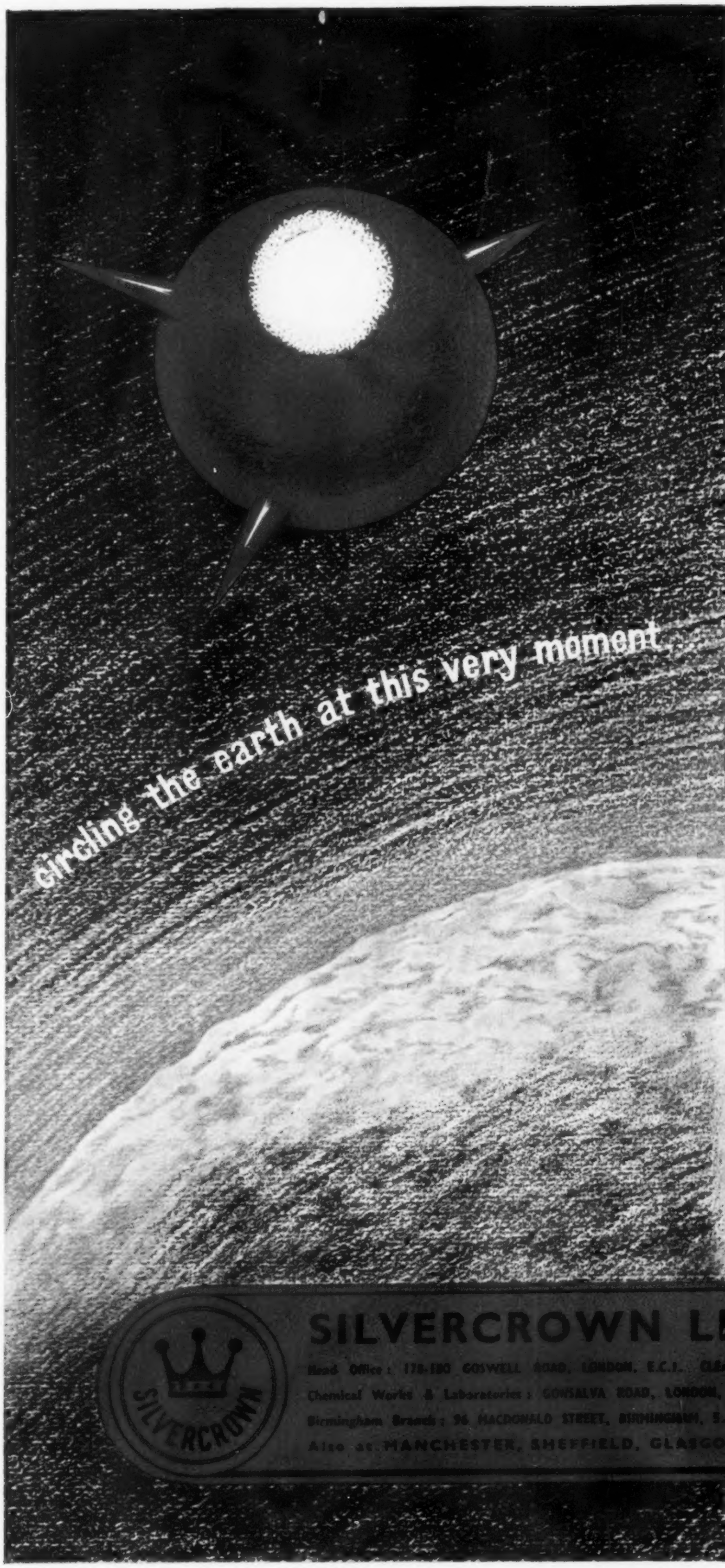

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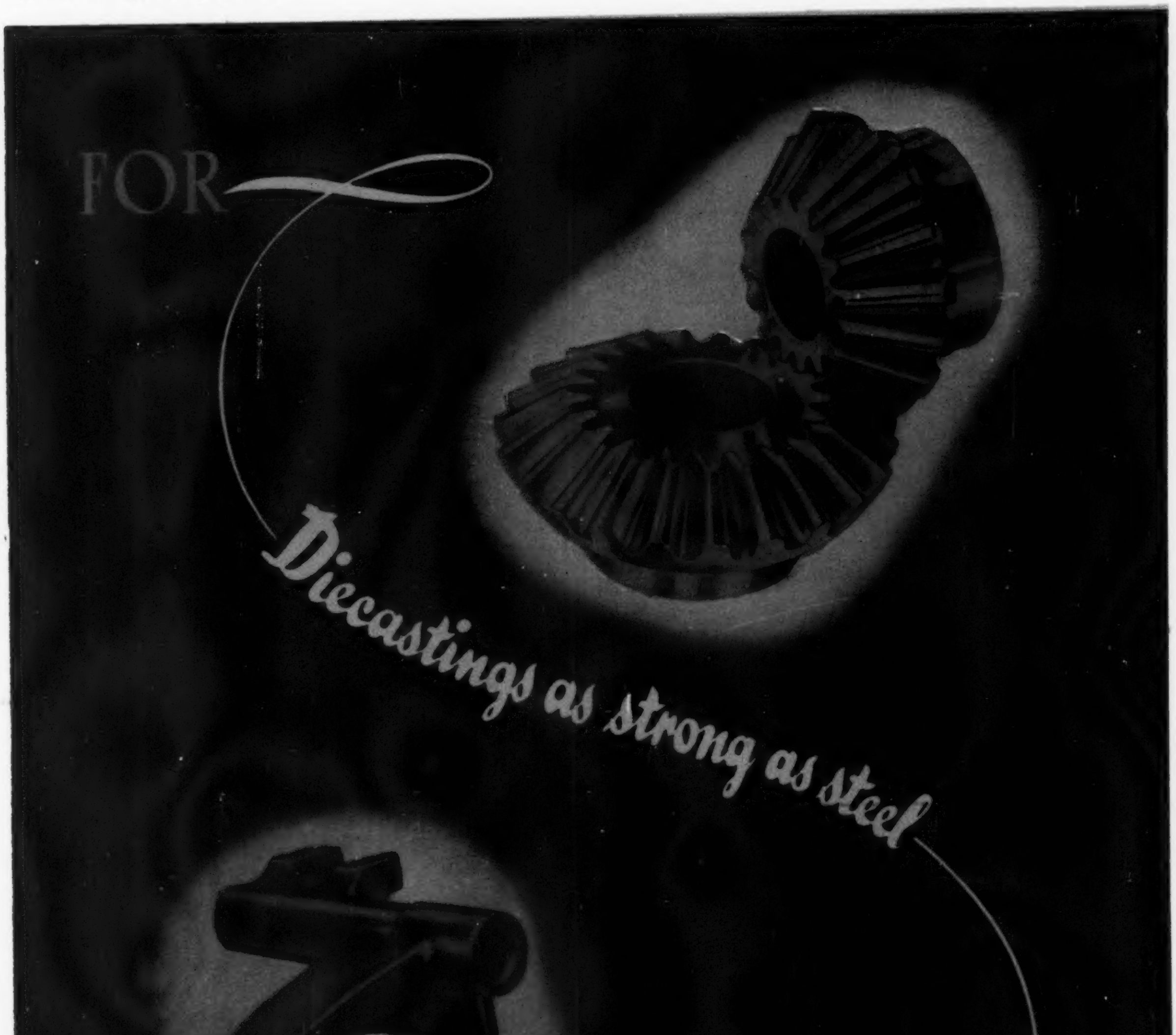
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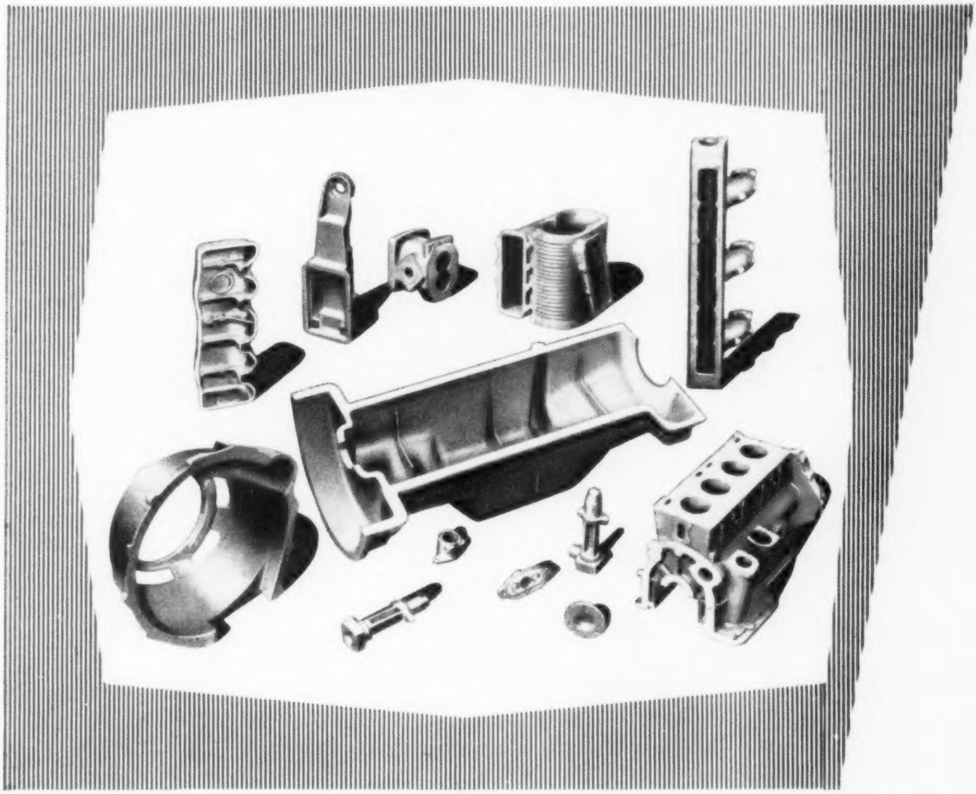

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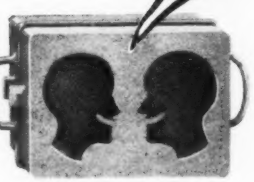

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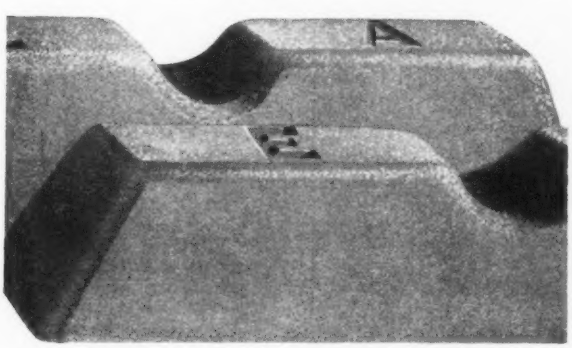

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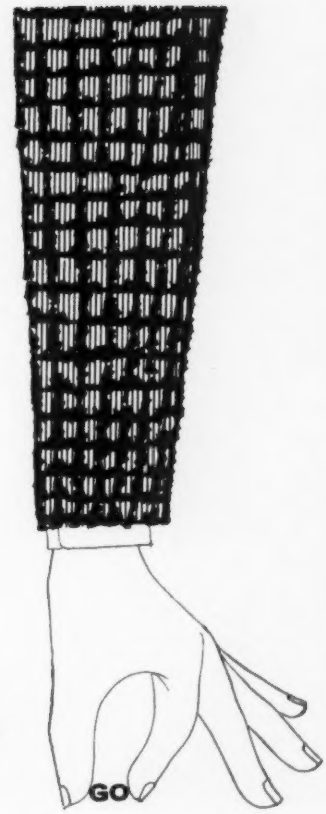

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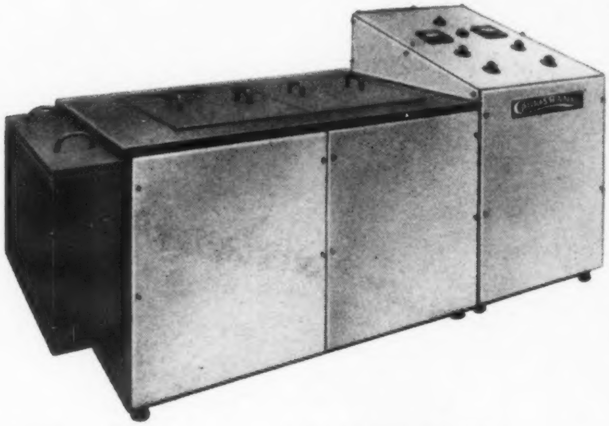

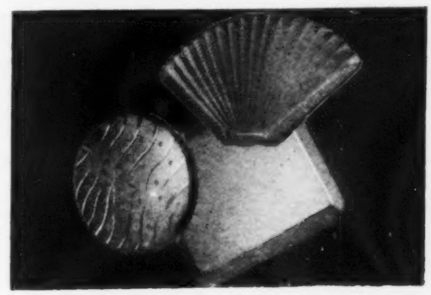

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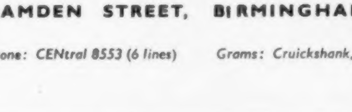

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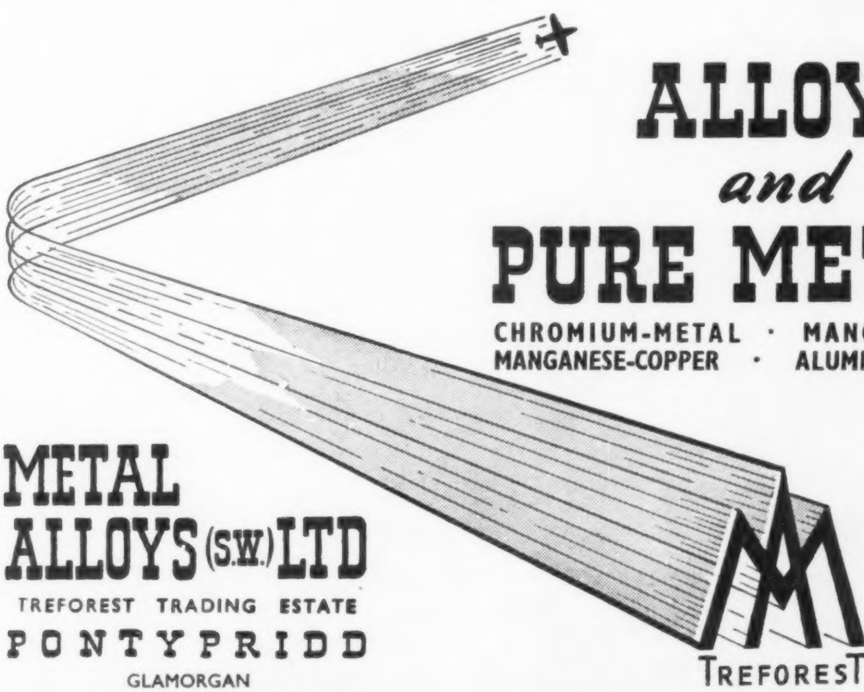

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